

# Proceedings

## 5<sup>th</sup> World Congress on Agroforestry

### “Transitioning to a viable world”

July 17-20, 2022  
Québec City, Canada

5<sup>th</sup> World  
Congress on  
**Agroforestry**  
.....>  
**Transitioning** to  
a Viable World



Proceedings of the 5<sup>th</sup> World Congress on Agroforestry:  
“Transitioning to a Viable World”. Québec, Canada, July 17-20,  
2022.

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## 5<sup>th</sup> World Congress on Agroforestry

On July 17<sup>th</sup>-20<sup>th</sup>, 2022, the 5<sup>th</sup> World Congress on Agroforestry: Transitioning to a Viable World, was held in Québec City, Canada, as well as in virtual mode. This congress, organized by Université Laval, in partnership with the International Union for Agroforestry (IUAf) and World Agroforestry (ICRAF), was an opportunity to stimulate an open and inclusive dialogue between various stakeholders from around the world including farmers, researchers, advisors, policy makers, and representatives from the government, the civil society and the private sector.

Agroforestry helps improve soil health, protect water quality, increase biodiversity, mitigate and adapt to climate change, and provide food security, health and revenues. It is an essential component of the needed ecological, energetic, social and economic transition. This critical transition can and must be achieved through a participatory collaboration process that builds bridges between research, policy decisions and field work.

The 5<sup>th</sup> World Congress on Agroforestry participated in creating or strengthening those connections by promoting knowledge sharing for a transition to a unified and healthy world.

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## Partners

### Gold



### Silver



### Bronze



## Cooperating Organizations



# Full Schedule

Preliminary schedule														
	Sunday, July 17		Monday, July 18		Tuesday, July 19 (Journée Québec)		Wednesday, July 20		Thursday, July 21					
Place	Grand Marché de Québec	Université Laval (Emerging Researchers Day)	Congress Center		Congress Center		Congress Center		Depends on the tour					
08:00 - 08:30 AM	Agroforestry Fair		Opening of the welcome desk		Opening of the welcome desk		Opening of the welcome desk		<div>Conférence at Université Laval: Agroforestry and Climate-Resilient Land Use: A Global Perspective</div> <div>Field tours</div>					
08:30 - 09:00 AM		Welcome	Opening & Plenary Session 1: Perspectives on Transition		Plenary Session 3: Governance of agroforestry initiatives		Workshops / Side Events: - Place of trees in food systems - Farmers Voices 1	Parallel Sessions 5						
09:00 - 09:30 AM		Historical perspective of agroforestry research and way forward												
09:30 - 10:00 AM		Coffee break												
10:00 - 10:30 AM			Coffee break (30 min)		Coffee break (30 min)		Coffee break (30 min)							
10:30 - 11:00 AM		Co-construction of knowledge, participation and role of scientists in participatory research	Plenary Session 2: Relation to Nature		Workshops / Side Events: - Modes d'appuis aux producteurs.trices - ICRAF Book launch	Parallel Sessions 2	Workshops / Side Events: - Take a break! - Farmers Voices 2 - Smallholder Agroforestry	Parallel Sessions 6						
11:00 - 11:30 AM														
11:30 - 12:00 AM														
12:00 - 12:30 AM		Lunch break	Lunch break		Lunch break & Lunch and Learn		Lunch break							
12:30 - 13:00 PM														
13:00 - 13:30 PM														
13:30 - 14:00 PM		Technologies and Agroforestry	Workshops / Side Events: - Presentation on technical tools		Parallel Sessions 1	Parallel Sessions 3	Plenary Session 4: the Agroecology-Agroforestry Nexus							
14:00 - 14:30 PM		Workshop : How to rock your PowerPoint presentation												
14:30 - 15:00 PM		Coffee break												
15:00 - 15:30 PM		Networking & Brainstorming for the Lunch and Learn	Posters & Coffee-break		Posters & Coffee-break		Coffee break (15 min)							
15:30 - 16:00 PM							Closing							
16:00 - 16:30 PM				Side event: Success Stories		Workshops / Side Events: - Adoption de l'agroforesterie : témoignage et outils (starts at 3:30 pm)	Parallel Sessions 4	Side Event of FTA (CIFOR-ICRAF)						
16:30 - 17:00 PM														
17:00 - 17:30 PM	Cocktail (This activity takes place in the Congress Centre)	Side event: IUAF General Assembly												
17:30 - 18:00 PM														
18:00 - 18:30 PM														
18:30 - 19:00 PM														
19:00 - 19:30 PM		IUAF cocktail												
19:30 - 20:00 PM														
20:00 - 20:30 PM														
20:30 - 21:00 PM														
21:00 - 21:30 PM														
21:30 - 22:00 PM														
22:00 - 22:30 PM														
22:30 - 23:00 PM														



## Parallel Sessions at a glance

Room 200A/B	Room 202	Room 304A/B	Room 203	Room 301B	Room 303A	Room 301A	Room 204B	Room 204A
<b>Time 1 : Monday, July 18, 2:00-3:30 pm</b>								
C1 - Biodiversity	A1 - Soils	D1 - Viable Climate	L1 - Perennial Crops	H1 - Development	O1 - Agroecology	K1 - Annual Crops	Workshop - Technical tools	J1 - Arid Climate
<b>Time 2 : Tuesday, July 19, 10:30 am-12:00 pm</b>								
C2 - Biodiversity	Workshop - Québec 1	D2 - Viable Climate	L2 - Perennial Crops	H2 - Development	O2 - Agroecology	K2 - Annual Crops	F1 - Economy	Side Event - ICRAF Book Launch
<b>Time 3 : Tuesday, July 19, 1:30-3:00 pm</b>								
C3 - Biodiversity	Workshop - Québec 2	Side Event - Agroforestry and Climate Adaptation Policies	L3 - Perennial Crops	H3 - Development	O3 - Agroecology	E1 - Food Security	F2 - Economy	M1 - Silvopasture
<b>Time 4 : Tuesday, July 19, 4:30-6:00 pm</b>								
C4 - Biodiversity	Workshop - Québec 3*	D3 - Viable Climate	L4 - Perennial Crops	H4 - Development	G1 - Society	E2 - Food Security	F3 - Economy	M2 - Silvopasture
<b>Time 5 : Wednesday, July 20, 8:30-10:00 am</b>								
Workshop - Farmers Voices 1	A2 - Soils	D4 - Viable Climate	L5 - Perennial Crops	I1 - Policies	G2 - Society	B1 - Water/Light	Workshop - Role of Trees in Food Systems	N1 - Food Forest
<b>Time 6 : Wednesday, July 20, 10:30 am-12:00 pm</b>								
Workshop - Farmers Voices 2	A3 - Soils	D5 - Viable Climate	Side Event - Take a Break	I2 - Policies	G3 - Society	B2 - Water/Light	Side Event - Tech-enabled Carbon Payment	N2 - Food Forest
<b>*Note: The 3rd Workshop Québec will take place at 15:30-17:00</b>								



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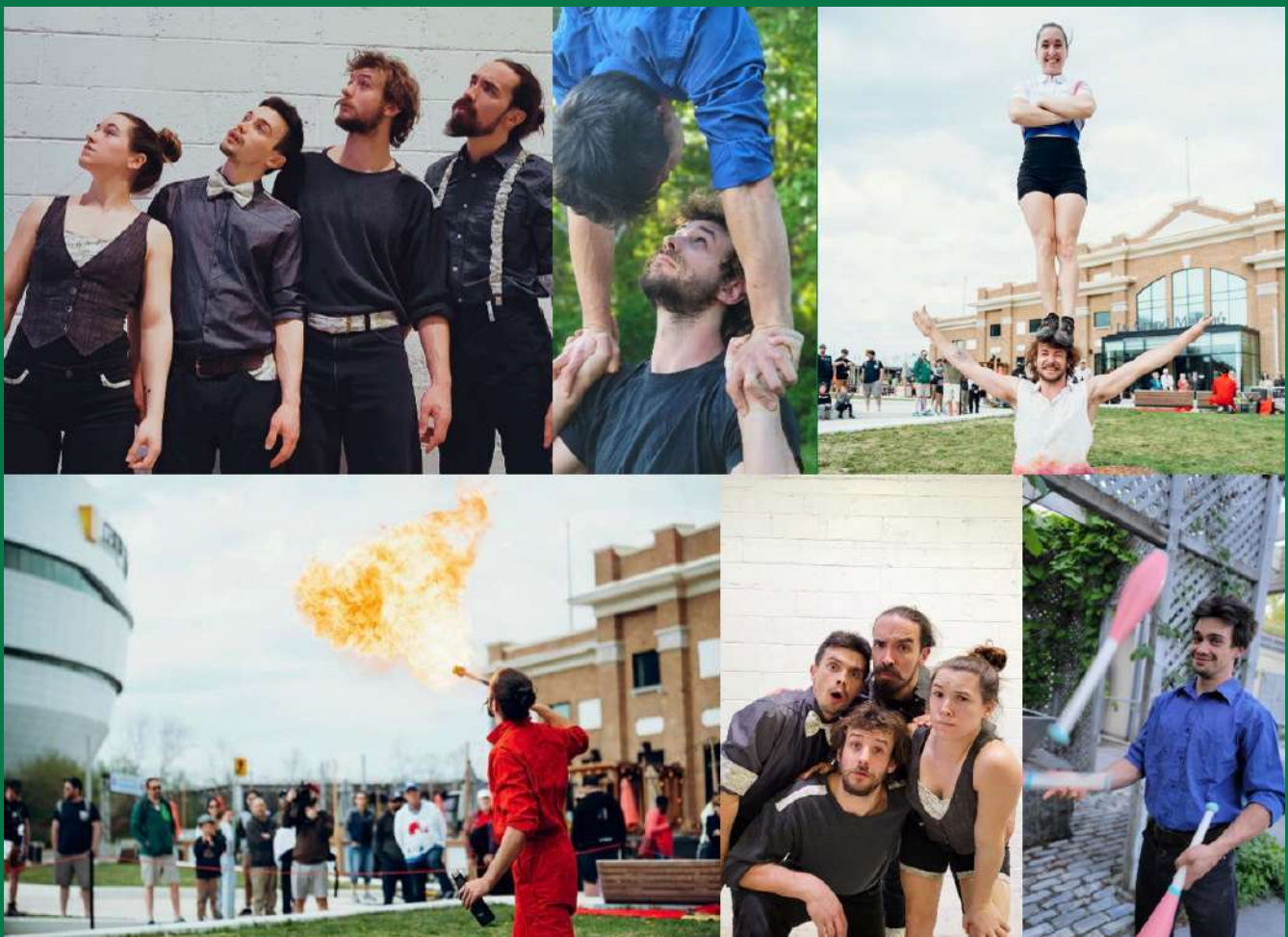
Sunday, July 17, 2022 : at the Agroforestry Fair and the Cocktail

## Circus

### Les 4apultés

When you sit in a catapult, you wonder how far you're going to be thrown. The *4apultés* is pretty much that. They launch themselves and always fall further than expected! With them, we can expect anything as soon as they embark on their creative machine; and it doesn't matter what is propelled into the air: juggling pins, a unicycle, or acrobats... why not!

A circus artist jumping out of a suitcase with his unicycle throwing juggling pins at two acrobats stacked on top of each other... On landing, everyone finds maximum pleasure!!!



Sunday, July 17, 2022

## Agroforestry Fair

### Grand Marché de Québec

Organized in collaboration by the Université Laval and the Association pour la commercialisation des produits forestiers non ligneux (Association for commercialization of non-timber forest products), the Agroforestry Fair is a free event which will take place at the Grand Marché de Québec.

With around 15 exhibitors, this event will offer the citizens of Québec City and of the world an exceptional chance to discover the products and services of the various exhibitors.

It will also be a gold occasion to come and listen to Québec professionals who will tell us about forest products of the province and several ways to integrate them in our dishes. Several activities and animations will highlight our forests and their richness.

### Booths

CPNCQ: Noix du Québec

Au jardin des noix

Champignon boréal

Les jardins cueilleurs

Les Choux gras, coopérative

Nature A T

Les airelles des frères

Conception Permanourricière

Domaine Small

La coop de l'arbre

Ecosociété

### Presentations (in French):

#### La foresterie vivrière, by Simon Blais

Between productive agricultural dynamic and natural forest dynamic, the « foresterie vivrière » (food forestry) – or gourmand forestry for gourmets – is about the management or the valorization of nurturing ecosystems on woody plots or wasteland.

This presentation will explain the limits of picking in nature, the potential of boreal plant domestication, of sylvopastoralism, of mycotouristic planning et of the development of the local forest food offer. The conference will end with the presentation of a cooperative project – *Forêt gourmande* – as well as a tasting of their product, at their booth.

### Chaga en vrai, by Roger Larivière

Chaga is a parasite mushroom of birch. Made popular in Occident only during the last few decades, chaga has been used for its benefits by Asian, Russian and Scandinavian people for a long time. Several recognized organisations (WHO, FDA, Health Canada) recognize it as a natural health product thanks to its antivirus, anti-inflammatory, antioxidant, anticancer, antidiabetic proprieties and its modular effects on the immune system.

### Les truffes de nos forêts, by Véronique Cloutier

What is truffles biodiversity in Québec? Do we own rare species to protect? Is there an economical potential in 2022? How do we seize the opportunity? These questions will be answered by this presentation on the unsuspected world of Québec truffles.

### Les arbres à noix pour le Québec, by Yvan Perrault

Walnut trees, hazel trees, white oaks, beeches and hickories are all happy in our harsh climate. Sometimes in clay soils, sometimes in acidic soils, they have unusual aspects, and they lend themselves to all mosaics of landscape management. They could help you be self-sufficient in nuts, their wood will cost a fortune someday, they produce delicious and nutritious dry fruits, here are the Nordic nut trees!



Sunday, July 17, 2022: during the Welcome Reception

## Poeme

la violence incline  
sa main râpeuse dans le giron de la terre  
en succionne la moelle  
beauté sauvage rongée  
entre ses mâchoires le jour recule

les champs ont la gorge sèche  
les gestes s'affament  
vous osez autrement le monde  
ses compositions désorganisées  
aux frontières liquides

l'érosion se désapprend  
vous éveillez le territoire  
d'une longue fatigue  
les étendues respirent vivaces  
aux rassemblement de vos savoirs

## Sophie-Anne Landry

Quebec author and poet, Sophie-Anne Landry writes to establish a sensitive dialogue with others. She seeks to explore individual and collective wounds in a desire for reconstruction. Winner of the Jean-Sébastien Pontbriand scholarships (2019) and the mention of the Alphonse-Piché prize (2017), his poetic sequel *Il fera peut-être naissance* was published by Art le Sabord (2017). In 2021, the *Épidermes* collective, co-directed with Mattia Scarpulla, is published by Tête Première. The same year, published by Écume, *Cosmogonie des corps: nos bouches des fenêtres*. This photo-poetry collection of the Bourrasques collective, of which she is the general director, was produced as part of a multidisciplinary and videopoetic project on the female body.

## Emerging Researchers Day

Organised on the Université Laval campus, this day will be the occasion for the new generation of agroforestry researchers to gather, get to know each other before the Congress. We invite all of you to take advantage of this occasion to start networking, because it often constitutes one of the best achievements of the scientific congress.

A rich program of conferences, panels and workshops to favor the discussion on leads and tools to create a more inclusive research, open and collaborative, open to the possibilities. Participants will be accompanied by senior experts and emerging researchers in this reflection on the importance of knowledges and exchanges, recognizing the expertise of another, sharing data and transdisciplinarity. These are unavoidable subjects in our field today. This linking between researchers identifying themselves as emerging and senior experts will allow to think on what has been accomplished in agroforestry, but also to project on what is awaiting us as professionals.

We wish that all the participants will profit from this day with the contacts they will develop and the reflections that they will harvest from them.

Facilitator: Vivian Valencia, Ph.D., Professor, Wageningen University

8:30 am

### Welcome remarks and icebreaker

Organizing committee & Vivian Valencia

9:00 am

### Historical perspective of agroforestry research and way forward

Meine Van Noordwijk, Principal scientist, CIFOR-ICRAF

*Break: 10:00 to 10:30 am*

10:30 am

## Co-construction of knowledge, participation and role of scientists in participatory research

Kurniatun Hairiah, Soil Scientist and Lecturer, Brawijaya University

Rafael Pompa, Farmer and Ph.D. student, UK

Meine van Noordwijk, Principal scientist, CIFOR-ICRAF

Terrylynn “Será:sera” Brant, owner, Mohawk Seedkeeper Gardens

Beatriz Oliver, Director International Programs, Seed Change

*Lunch break: 12:30 to 1:30 pm*

1:30 pm

## Technologies and agroforestry: challenges and opportunities

Marie Gosme, INRAE, France

2:15 pm

## The only young face in the room: moving youth agrifood systems representation forward in science and policy

Genna Tesdall, Director, Young Professionals for Agricultural Development

*Break: 3:15 to 3:30 pm*

3:30 pm

## Workshop: Networking & Brainstorming for the Lunch & Learn

4:15 pm: Summary, comments and closing remarks

TUESDAY, JULY 19

LUNCH & LEARN

12:00 pm

6:00 to 8:00 pm, in the hall of the Congress Center

## Welcome Reception

Meet your colleagues and start your networking in a festive atmosphere, with some surprises on the menu.





Hall of the 4<sup>th</sup> floor and scene of the plenary room

Embroidery and sculptures exposition

## Les arbres sont fatigués

by Roxy Russell

[www.roxyrussell.co.uk](http://www.roxyrussell.co.uk)

@roxyrussellart



Roxy Russell is the artist presenting the four works exhibited throughout the congress space during the 5<sup>th</sup> World Congress on Agroforestry. *Et s'il n'y avait plus d'arbres ?* (What if there were no trees?) is presented in two parts: on the stage and along the corridor near the entrance. *Où aller ?* (Where to go?) and *Empreintes d'arbres qui ne sont plus* (Traces of trees that are no longer) can be found in the main hall.

A sense of disconnection with the environment is at the core of Roxy Russell's artistic research. Her work reflects questions about our relationship with nature, the cohabitation between human and non-human, the way plants are manipulated, exploited, aligned and dominated.

Although she uses various materials and techniques, the methods she chooses usually require a repetition of the same action and a commitment over time. In search of coherence with the living and a feeling of continuity, she tries to create a relationship with her environment.

Roxy Russell was born in Edinburgh (Scotland) in 1988 and immigrated to Geneva (Switzerland) with her family in 1998. After graduating from the Valais School of Art (EDHEA, Sierre, Switzerland) in 2013, she travelled and participated in various exhibitions and residencies in Great Britain, Ireland, Switzerland, Thailand and India. In 2019, she decided to move to Quebec (Canada) to pursue a master's degree in Visual Arts at Université Laval that she completed in 2021. During her time in Canada, she took part in different events and exhibitions such as "Fresh Paint / New Construction" at Art Mur Gallery in Montreal, "DE(S)CONNEXIONS" at Le Lobe in Chicoutimi, and presented her solo exhibition "The Trees Are Tired" in Quebec. Roxy moved to Portugal in February 2022.



Monday, July 18, 2022

8:30 am, Room 200A/B

## Opening Session

Voices from Québec and from all over the world will unite to the organizing committee of the 5<sup>th</sup> World Congress on Agroforestry to officially welcome participants to Québec and pave the way for discovery, discussion, and sharing.

### Speakers:

- Rémy Vincent, Grand Chief of the Huron-Wendat Nation,
- Andrée Levesque Sioui, Singer and poet from the community of Wendake,
- Alain Olivier, Cochair of the 5th World Congress on Agroforestry,
- Paul Doyon, First vice-president of the Union des producteurs agricoles of Québec,
- Isabelle Ahou Fram Tano, Cocoa producer and vice-president of the FAHO cooperative in Ivory Coast.



9:00 am, Room 200A/B

## Plenary Session: Perspectives on Transition

Human and ecological systems are at the breaking point. While climate change, loss of biodiversity, pollution and growing economic and social inequalities threaten and weaken the health of populations, ecosystem balances and social cohesion, the need for a transition to make the world viable is clearer than ever. Frequently used in a host of fields, the concept of transition and its implications, both practical and philosophical, deserve to be addressed in order to better understand its meaning and scope. This first plenary will give the floor to people from different backgrounds to better understand what a transition is and the role that agroforestry can play in facilitating it, from the farm to the planet scale.

### The Crucial Positive Climate Tipping Point

Dennis Garrity, Chair of the board of the Global EverGreening Alliance

### Planting trees to save our cocoa production

Isabelle Ahou Fram Tano, Cocoa producer and vice-president of the FAHO cooperative in Ivory Coast

### Natural infrastructures to accelerate ecological transition

Jérôme Dupras, Professor in the Department of Natural Sciences at the Université du Québec en Outaouais

### My windbreaks, source of pride and biodiversity

Christian Taillon, Organic dairy farmer in Saint-Prime, Saguenay–Lac-Saint-Jean

### The agroecological transition at the territorial scale: a sociological perspective

Claire Lamine, Sociologist attached to the Ecodevelopment Unit of INRAE in France

*Coffee break: 10:30 to 11:00 am*

11:00 am, Plenary Room

## Plenary Session: Relation to Nature

Agroforestry prompts a redefinition of the relationship between societies and the environment. The human capacity to manage land by various arrangements of plants and trees refers to the notion of domestic nature, proposed by Philippe Descola according to a perspective which is both ethnographic and naturalist. The idea of a domestic nature abolishes the dualism between nature and culture and makes it possible to contemplate how humans belong to ecosystems, regardless of how these ecosystems are managed. The question however is whether agroforestry can help establish a more equitable relationship between human needs and the needs of countless non-humans within ecosystems, long neglected in modern Western understanding of the environment. In order to extend this reflection, this Plenary Session brings together various perspectives on the relationships with nature that emerge through agroforestry. We bring together indigenous, peasant and scientific perspectives to fuel the discussion.

### Relation to Nature: a Testimony

Michèle Audette, Canadian senator and former President of the Native Women's Association of Canada

### Close Your Eyes and See the Forest

Terrylynn Brant, Owner and operator of Mohawk Seedkeeper Gardens

### Historic struggle against trees: where do we stand?

Rodolphe de Koninck, Professor Emeritus at the Université de Montréal

### « We don't fear diversity ». Feminist learning of agroforestry

Miriam Nobre, Agronomist and lecturer for the Latin America's Integration Inter-Units Graduate Program (Prolam/USP) of the University of Sao Paulo

### Peasants of the world, inventors of agroforestry

Geneviève Michon, Research Director at the French National Research Institute for Sustainable Development (IRD)

*Lunch break: 12:30 to 2:00 pm*

Exposition room, 4<sup>th</sup> floor

Sculpture

[www.jiwanlarouche.com](http://www.jiwanlarouche.com)

@jiwankenobi

## The Tree Graces – 2022

by Jiwan Larouche

Steel, plaster, urethan, aluminum, metallic fabric, thread, beads, stuffing, gold sheet

Jiwan's work is built around the concept of intimacy, including relationships with the self, others and nature. In this giant sculpture, three beings with human legs are holding each other on an angular rock, a symbol of our uncertain society. Supportive of each other, they are inspired from potatoes, which need each other to grow. The 84 embroidered leaves create a surprising canopy. With this piece, the artist wants to plant a seed of solidarity amongst the public.



Jiwan is a sculptor who comes from the puppet industry and show business. Their artistic practice often shows hybrid creations, where body parts meet vegetal and animal worlds. Their research focuses on body diversity, fluidity of one's identity, but also on the relationship between human and nature. Jiwan's work often starts with molding of human body parts in plaster, on which various structures are added progressively, covered with embroideries and ornaments which can evoke a theatrical universe.

Jiwan comes from Lévis and now lives and works in Quebec City, Canada. They completed a Bachelor's degree in Translation but finally chose a more creative path in 2016, co-founding craft businesses, working as little hands and making puppets for the show business, including productions at Le Diamant and Quebec's Museum of Civilisation. Jiwan decided to complete la Maison des métiers d'art's Sculpture program to master as many materials as possible and be able to lead their own artistic projects. They also were part of Montreal TOHU Falla project as a sculptor in the summer of 2021.

2:00 pm

## Parallel Sessions

Room 204B

### Workshop - Presentation of technical tools

This workshop aims to introduce participants to different tools or techniques to facilitate decision-making regarding agroforestry interventions. The tools presented will deal with different types of agroforestry systems in tropical and temperate environments. The first tool presented will be Hi-sAFe, which simulate in a 3D model the growth of trees and crops, and the hisafer package will be demonstrated. Two FAO tools that measure the impacts of different climate actions will then be presented. These are the ABC-Map and NEXT tools.

with Marie Gosme, INRAE, France ; Martial Bernoux, FAO & Daniel Dionisio, FAO.

Language: English

If you want to follow along the hisafer package demonstration, you can take these steps before joining the workshop. For those who have a computer, they should have installed the package before because it takes time to download:

type in R:

```
install.packages("devtools")
devtools::install_github("kevinwolz/hisafer")
```

The first time you install it, there might be a lot of errors like "no package named xxxx was found", you just need to install these packages (either manually with `install.packages()` or through the menu Tools>Install packages... of Rstudio if you are using Rstudio). That's because the developpers of some of the packages that hisafer uses did not declare these packages as dependencies, so they are not downloaded automatically when installing hisafer. But you have to do it only once and after that, it should work easily.

#then next time you just have to type:

```
library(hisafer)
hop<-read_hisafe_example() #to read the built-in simulations that come with hisafer
hop$metadata #to see the available simulations in this example ... it can take some time
plot_hisafe_monthcells(hop = hop,
```

```
variable = "monthRelativeDirectParIncident",
colfacet = "Year",
rowfacet = "SimulationName",
years = 1995:2000,
months = 7,
trees = FALSE,
canopies = FALSE) #to get the map of solar radiation reaching the ground in July each year, in the 3
compared systems.
```

Room 202

## A1. Transitioning to Healthy Soils

### Soil organic carbon accumulation rates in tropical silvopastoral systems of southern Mexico

\*Deb Raj Aryal, CONACYT-UNACH, Mexico

Danilo Enrique Morales Ruiz, Universidad Autónoma de Chiapas, Mexico

Gilberto Villanueva López, El Colegio de la Frontera Sur, Mexico

Fernando Casanova Lugo, Tecnológico Nacional de México, Mexico

René Pinto Ruiz, Universidad Autónoma de Chiapas, Mexico

Francisco Guevara Hernández, Universidad Autónoma de Chiapas, Mexico

Mariela Reyes Sosa, CONACYT-UNACH, Mexico

José Apolonio Venegas Venegas, CONACYT-UNACH, Mexico

Juan Carlos Lopez Hernandez, Universidad Autónoma de Chiapas, Mexico

Aida Moya Moya Montes, Universidad Miguel Hernández, Spain

Silvopasture, a livestock-agroforestry, is recognized as one of the alternatives to enhance soil organic carbon (SOC) sequestration in grazing lands. The studies on the role of silvopastoral systems (SPS) for carbon sequestration are increasing but the SOC sequestration potentials are still limited. In this study, we assessed the SOC sequestration rates of two tropical silvopastoral systems: 1) dispersed native trees on pasturelands (DTS), and 2) fodder banks of *Leucaena leucocephala* (LFB) in southern Mexico. We quantified the annual SOC sequestration rates by simultaneous measurements of SPS and adjacent open pasturelands (OP), where the stock differences were divided by the age of the SPS. For this analysis, we consolidated published and unpublished data from various parts of southern Mexico. The mean SOC stocks to 30 cm depth were 153 (95% confidence interval: 128.6 - 177.4) Mg C ha<sup>-1</sup> for DTS, 144.4 (117.7 – 171.2) Mg C ha<sup>-1</sup> for LFB; while that of OP was 95.4 (76.8 – 114.0) Mg C ha<sup>-1</sup>. We found that SPS in southern Mexico, on average, act as soil carbon sinks, that can contribute to partly offset C emissions from the livestock sector. The average SOC sequestration rates were 0.52 (-0.22 and 1.25) Mg C ha<sup>-1</sup> yr<sup>-1</sup> in DTS and 0.76 (0.09 and 1.44) Mg C ha<sup>-1</sup> yr<sup>-1</sup> in LFB. SOC sequestration rates in a natural forest succession ranged between 0.13 and 2.0 Mg C ha<sup>-1</sup> yr<sup>-1</sup> in the region. Although SOC accumulation rates were statistically higher than zero, the variations between sites indicate that many other factors can affect SOC sequestration rates in these SPS. Initial SOC stocks, time after deforestation, land-use history, age of the silvopasture, SPS arrangements, land management, stocking rates, other nutrients, soil organisms, heterotrophic respiration, species composition, and root architecture are some of the important factors to consider while assessing SOC sequestration potentials.

### Assessing legume tree and shrub impacts on nitrogen cycling in banana cropping systems

\*Antoine Galiana, CIRAD, France

Marie Sauvadet, CIRAD, France

Alice Prochasson, IT2, France

Mathieu Coulis, CIRAD, France

Trees in cropping systems provide a wide range of services such as soil carbon storage, erosion regulation, or promotion of soil biodiversity and microbial symbioses. However, modalities and consequences of tree or shrub species introduction into banana cropping systems have seldom been studied. In order to improve the general knowledge on tree management in these systems, the BANABIO research program relied on a participatory approach for designing bio-diversified exportation banana cropping systems with local farmers. A banana-based agroforestry system was set up in 2018 in comparison with both conventional and organic management systems in a CIRAD experimental research station located in Martinique. The agroforestry system associated several legume tree and shrub species (600 individuals.ha<sup>-1</sup> *Cajanus cajan*, and 360 trees.ha<sup>-1</sup> *Inga ingoides* and *Indigofera zollingeriana*) that were interplanted with banana (1200 individuals.ha<sup>-1</sup>) at the beginning of 2019. At the end of 2019, *Cajanus cajan* were replaced by *Theobroma cacao* (600 trees.ha<sup>-1</sup>) used as a complementary crop to bananas. Since 2019, plant growth and species performance have been followed through height and circumference measurements, biomass restitution through pruning, residues N content and N<sub>2</sub> fixation estimated by  $\delta^{15}\text{N}$  natural abundance. Tree management led to an increase of pruning biomass restitution through the production cycles, i.e. from 2 t DM.ha<sup>-1</sup> of *Cajanus cajan* residues in 2019 to 5 t DM.ha<sup>-1</sup> of *Inga* and *Indigofera* residues mixture in 2021, leading to a global restitution of about 80 kg N.ha<sup>-1</sup> in 2021. Further analysis of  $\delta^{15}\text{N}$  values in *Inga* and *Indigofera*, in parallel to those of banana and other non-N<sub>2</sub>-fixing reference species, will allow to determine the proportion of N restituted from biologically fixed N. Soil C and N increases since the plantation suggest a positive impact of legume tree and shrub introduction on soil fertility, and their good compatibility with banana cropping systems.

### Natural terrace formation in agroforestry systems for soil conservation in uplands of northwest Vietnam

\*Van Hung Do, Department of Crop Production Ecology, Swedish University of Agricultural Sciences (SLU), Sweden

Ingrid Öborn, Swedish University of Agricultural Sciences (SLU), Sweden

Göran Bergkvist, Department of Crop Production Ecology, Swedish University of Agricultural Sciences (SLU), Sweden

Van Thach Nguyen, World Agroforestry (ICRAF) Vietnam, Vietnam

Nguyen La, World Agroforestry (ICRAF), Vietnam

Rachmat Mulia, World Agroforestry (ICRAF), Vietnam

A. Sigrun Dahlin, Swedish University of Agricultural Sciences (SLU), Sweden

Agroforestry has long been recognized as a more sustainable way to produce food, and other products and services in sloping areas, than agriculture based on sole-crop cultivation of annual crops. However, the dynamics of soil physical traits, and soil and nutrient losses during the transition to agroforestry, have received little attention. Our aim was to evaluate the transition from sloping cultivation without terraces into soil conservation farming with terraces using agroforestry with grass strips. We compared two-agroforestry systems on sloping land in northwest Vietnam, one that included longan (*Dimocarpus longan* L.)-mango (*Mangifera indica* L.)-maize (*Zea mays* L.)-forage grass (Guinea grass-*Panicum maximum*) (LMMG), and one that included son tra (*Docynia indica* (Wall.) Decne.)-coffee (*Coffea arabica* L.)-forage grass (STCG) with sole-cropped maize (SM) and sole-cropped coffee (SC), respectively. During four years, we quantified soil and nutrient losses by soil traps and evaluated terrace formation by erosion pins placed above grass strips and used them to estimate the volume of the formed terraces. The results showed that LMMG and STCG systems reduced losses of soil, organic carbon and related

nutrients (N, P, and K) significantly compared to SM and SC already in the first two years, but the impacts were greater in years 3 and 4. On average, from years 2 to 4, agroforestry systems reduced soil, organic carbon, N, P, and K losses by 28–67%, 32–63%, 30–65%, 41–70% and 15–69%, respectively. In addition, the terraces were generally formed as the systems developed, through the gradual deposition of soil sediments above the living grass strips and trees. Our findings revealed that the transition to agroforestry with grass strips on sloping land reduced soil loss (and carbon and nutrient loss) through terrace formation and could be a useful management practice and viable option for sustainable agricultural systems in steep slope areas.

### Conversion of savannah to cocoa agroforestry systems or other land uses: medium and long-term impacts on different soil organic C pools

\*Eltson Eteckji Fonkeng, ICRAF (World Agroforestry), Cameroon

Tiphaine Chevallier, Eco&Sols, IRD, CIRAD, INRAE, l'Institut Agro, France

Seguy Enock, ICRAF (World Agroforestry), Cameroon

Nancy Rakotondrzafy, IRD, France

Lydie Chapuis-Lardy, Eco&Sols, IRD, CIRAD, INRAE, l'Institut Agro, Senegal

Marie Sauvadet, CIRAD, France

Fritz Oben Tabi, University of Dschang, Cameroon

Jean-Michel Harmand, CIRAD, UMR Eco&Sols, Cameroon

Afforestation of savannah with cocoa agroforestry systems (cAFS) is a common farmer practice in Cameroon previously described as a sustainable production option. Nevertheless, the effects of afforestation of savannah with cAFS on C turnover and content, and the factors controlling C accumulation and stabilization are unknown. Different systems settled on savannah were compared: cropland ( $\approx 5$  years old), cocoa monoculture ( $\approx 10$  years old) and cAFS (from 20 to 60 years old) shaded by different tree species (*Albizia adianthifolia*, *Canarium schweinfurthii*, *Dacryodes edulis*, *Milicia excelsa*, *Ceiba pentandra*). We used savannah and nearby forest patches as controls. Soils were orthic ferralsols with 9–15% clay content. Soil analysis was performed on the 0–10 cm soil layer for: organic C content, C distribution in soil particle size fractions (0–20  $\mu\text{m}$ , 20–50  $\mu\text{m}$ , and 50–2000  $\mu\text{m}$ ), and nutrient contents. Soil  $\delta^{13}\text{C}$  was analysed for studying how the change from savannah grasses (C4 plants) to other vegetation (C3 plants) affected soil C turnover. The amount of annual litter input and its nutrient content were also analysed. Conversion of savannah to cAFS significantly increased soil C to the same level as soil C under nearby forests (Figure 1). Conversion of savannah to annual cropland or cocoa monoculture resulted in a non-significant decrease in soil C. After conversion of savannah to other land uses, more than 70% of soil C derived from C4 plants was lost within 10 years and then remained almost unchanged. Contrastingly, soil C derived from C3 plants increased significantly in cAFS. The C accumulation occurred both in the 50–2000  $\mu\text{m}$  and 0–20  $\mu\text{m}$  soil fractions, and was linked to cumulative higher litter inputs in cAFS than in other systems. Soil C under the different shade tree species was positively linked to soil pH,  $\text{exch. Ca}^{2+}$  and litter Ca content. Afforestation of savannah with cAFS appears as a valuable option for soil carbon sequestration.

### Soil fertility after a prescribed burning combined with silvopasture in Galicia (NW Spain)

Nuria Ferreiro-Domínguez, University of Santiago de Compostela, Spain

Antonio Rigueiro-Rodríguez, University of Santiago de Compostela, Spain

\*María Rosa Mosquera-Losada, University of Santiago de Compostela, Spain



In the last years, the land abandonment in mountain areas of Galicia (NW Spain) linked to Nature 2000 has increased the accumulation of fuel in the landscape. Consequently, the risk of forest fires of high severity is very high and is aggravated by climate change which means that adaptation strategies are needed to avoid an increase in the devastating effects of forest fires. The combination of prescribed burnings and silvopasture is a cheap alternative to reduce the fire risk. However, prescribed burnings and silvopasture can modify the soil properties and therefore the landscape. This study aimed to evaluate the effect of a prescribed burning combined with silvopasture on soil fertility in a mountain area of Galicia (Os Ancares Lucenses). In February 2019, a prescribed burning was carried in that area of Galicia. After the prescribed burning, the area was divided into two plots, being one plot grazed with horses and the other plot maintained without grazing. Moreover, a control plot was established without burning and grazing. Composite soil samples were collected at different soil depths (0-3 cm and 3-10 cm) before and after prescribed burning and after grazing. In the laboratory, soil pH and the total concentration of cations in the soil were estimated. Data were statistically analysed with ANOVA. The results showed an increase in soil pH and total concentration of P, Na, Mg, Fe, Cu, Mn and Zn after the silvopasture probably due to the activation of nutrient cycling by grazing. Therefore, the combination of prescribed burnings and silvopasture could be used as a strategy to reduce the fire risk in the current situation of climate change at the same time that soil fertility is improved. Acknowledgements: This work was supported by the INTERREG-SUDOE project Open2preserve and the Pilot Program of the University of Santiago de Compostela (USC) for the hiring of distinguished research staff - call 2021, funded under the collaboration agreement between USC and Banco Santander, for the years 2021-2024.

### Changes in soil nutrient status under spatial geometries of poplar (*Populus deltoides*) based agroforestry system in semi-arid ecosystem of India

\*Chhavi Sirohi, Department of Forestry, CCS Haryana Agricultural University, India

Arun Kumar Handa, ICAR- Central Agroforestry Research Institute, India

Parvinder Kumar, KVK, Karnal, CCS Haryana Agricultural University, India

Ravinder Singh Dhillon, CCS Haryana Agricultural University, India

Karan Singh Ahlawat, CCS Haryana Agricultural University, India

Sushil Kumari, CCS Haryana Agricultural University, India

Poplar (*Populus deltoides*) a promising agroforestry tree species recognised for preventing land degradation, achieving long-term biological production on a sustainable basis and economic returns in short period of time. The tree enriches the soil by adding significant amounts of leaf litter resulting in enhanced soil fertility in terms of soil organic carbon (SOC), available N, P, and K. The study was conducted to investigate the changes in soil properties under various spatial geometries of four year old poplar based AFS in semi-arid region of India, with different spacings, i.e. 3×3m, 4×3m, 5×3m, 6×3m, 7×3m and 8×3m of poplar intercropped with wheat. We enumerated soil properties such as pH, electrical conductivity (EC), SOC, and available N, P, and K at soil depth of 0-15 cm and deliberated their spatial variability in relation to various spatial geometries of the poplar. Soil pH and electrical conductivity improved/lowered under various spatial geometries of poplar plantations as compared to sole crop. The soil organic carbon was found higher in 3×3 and 4×3 m tree spacing after harvesting of wheat crop. The accumulation rate of SOC increased with the decreasing in tree spacing and found maximum at 0.70 percent with 3×3m spacing and followed the order 4×3m > 5×3m > 6×3m > 7×3m > 8×3m > control plot. The available soil N, P and K increased considerably under various spatial geometries of poplar-based agroforestry system in comparison to control. The highest available soil N (235.3 kg ha<sup>-1</sup>), P (16.2 kg ha<sup>-1</sup>) and K (290.4 kg ha<sup>-1</sup>) were recorded under 3×3m spacing compared to 4×3m, 5×3m, 6×3m, 7×3m, 8×3m and sole cropping after harvesting of wheat crop.

Farmer's video: agroforestry in France

Room 200A/B

## C1. Transitioning to Biodiversity

Cumulative evidence of the positive effects of agroforestry systems on multiple ecosystem services using data from meta-analyses

\*Marc-Olivier Martin-Guay, Université du Québec en Outaouais, Canada

David Rivest, Université du Québec en Outaouais, Canada

In the last three decades the number of publications on agroforestry has steadily increased and meta-analyses on the topic are increasingly common. The evidence shows that agroforestry can improve multiple ecosystem services when compared to conventional agriculture. However, these meta-analyses were often carried out at a regional scale or focused on a few ecosystem services. Compiling all available databases from meta-analyses linking agroforestry to ecosystem services, we performed a meta-analysis at the global scale that included multiple ecosystem services. We compiled 1549 independent observations from 244 studies. Overall, agroforestry systems improved ecosystem services by an average of 18% when compared to conventional agriculture systems. Carbon sequestration and stocks were higher within agroforestry systems while CH<sub>4</sub> and N<sub>2</sub>O soil emissions were similar. Crop and biomass production was similar in both systems, with the exception of grass biomass, which was usually higher in agroforestry systems. Soil fertility was generally improved within agroforestry systems, with higher organic matter, C, N and P concentrations, cation-exchange capacity, and lower soil bulk density. Soil water content and water infiltration were also improved within agroforestry systems. Although soil conditions are improved when trees are present, agroforestry systems generally do not translate into greater agricultural production, probably due to a greater influence of light competition. These results indicate that agroforestry systems have positive effects on multiple ecosystem services and could help mitigate climate change.

Scaling up biodiversity conservation through climate-smart agrosilvopastoral practices lessons learned from the BioPaSOS project

\*Alejandra Martínez-Salinas, CATIE - Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica

Juan Edduardo Betanzos-Simon, CATIE - Centro Agronómico Tropical de Investigación y Enseñanza, Mexico

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Edwin Pérez Sánchez, CATIE - Centro Agronómico Tropical de Investigación y Enseñanza, Mexico

Claudia J. Sepúlveda L., CATIE, Costa Rica

Ibrahim Muhammad, CATIE, Costa Rica

Mexico is considered a hotspot for biodiversity conservation, however nearly 110 million ha of its territory is dedicated to livestock production (LP). LP frequently takes place in lands that have suffered deforestation and show some degree of degradation. The Scaling up biodiversity conservation through climate-smart agrosilvopastoral practices in landscapes dominated by cattle-raising systems in three regions of Mexico also known as the BioPaSOS project has been working for

the last five years in the states of Jalisco, Chiapas and Campeche promoting biodiversity conservation through the establishment of learning communities based on four pillars: i. capacity building; ii. research, iii. producing technical inputs for decision-making and iv. fomenting or strengthening territorial alliances. BioPaSOS has strengthened the capacities of more than 1200 farmers (22% women) via its Field Farmers Schools and have impacted over 15,000 ha of lands across its implementing territories. Over twenty-five different studies have been conducted (ten of them include data from all three states) covering themes from carbon storage capacity of different silvopastoral land uses to LP chains and market studies, it has also promoted the creation of sustainable LP working groups and recently has accomplished the signing by the heads of the Agriculture Secretariats of Jalisco, Chiapas, and Campeche of a Sustainable Livestock Declaration. However, many challenges remained in these territories to effectively transition to a sustainable LP, for instance there is a profound lack of knowledge and understanding of the value of biodiversity accompanied by a persistent mismatch between public policies directed to biodiversity conservation and those focused on increasing productivity which is worsen by a lack of coordination between environmental and agricultural agencies. Farmers although interested in implementing sustainable practices have very little access to training and funding mechanisms. There is a critical need to foster inter-agencies collaboration to effectively promote sustainable development.

### Using local ecological knowledge to identify suitable shade tree species a review of the ShadeTreeAdvice methodology

\*Clément Rigal, CIRAD, France

Sigrun Wagner, Manchester Metropolitan University, United Kingdom

Mai Phuong Nguyen, World Agroforestry (ICRAF), Vietnam

Laurence Jassogne, TerraQ Pte.Ltd, Singapore

Philippe Vaast, CIRAD, France

Context: The promotion of agroforestry practices is contingent upon the identification of locally suitable shade tree species. The ShadeTreeAdvice methodology intends to support this identification, through increased reliance on farmers' local ecological knowledge to document large pools of tree species and their provision of ecosystem services (van der Wolf et al., 2016). The methodology is supplemented by an online decision-support tool to tailor tree species selection to individual farmer's needs ([www.shadetreeadvice.org](http://www.shadetreeadvice.org)). Since its inception in 2016, the methodology was applied in eight coffee and cocoa growing areas across the globe. Objective & Method: We reviewed the results from the eight ShadeTreeAdvice studies to draw general lessons on shade tree species and their provision of ecosystem services in tropical farming systems. We also assessed the validity of the methodology and suggested improvements, based on trials and feedbacks from practitioners of the methodology. Results & Discussion: More than 180 tree species and their provision of more than 10 ecosystem services were documented in the eight ShadeTreeAdvice studies, validating the use of this methodology to support the identification of suitable shade tree species. The review highlighted the importance of trade-offs between environmental services and economic benefits, and the need to better take into account the impacts of shade trees on farming practices on top of their provision of ecosystem services. In future studies, suggested improvements in the methodology will allow the comparison of tree performances in monoculture vs in agroforestry systems. Furthermore, ShadeTreeAdvice practitioners will benefit from improved pathways to validate the outputs of the decision support tool. Finally, investigating the relationships between shade tree species' functional traits and their provision of ecosystem services will enable the generalization of results to new or uncommon shade tree species.

### Functionality of indicator biodiversity components in indigenously managed farming systems of Eastern Himalaya

\*Bhoj Kumar Acharya, Sikkim University, India

Most of the biodiversity research across the world is focussed in forest ecosystems and protected area network but recent researches have highlighted the importance of human modified landscapes in retention and conservation of various biodiversity components. Eastern Himalaya is a part of Himalayan biodiversity hotspots but has also witnessed significant biodiversity loss in the past few decades, especially due to conversion of forests into agricultural areas or developmental sites. The region represents unique indigenously managed farming systems (IFS) which is very rich in germplasm including wild biodiversity. In this study we assessed the role of these IFS in retention of two indicator taxa (birds and butterflies) using functional diversity indices. The birds and butterflies were sampled using point count methods along the transects covering three major IFS (Farm-based Agroecosystems- FA, Large Cardamom-based Agroecosystems-LCA and Mandarin Orange-based Agroecosystems-MOA) along with natural forest ecosystem-NF in the Eastern Himalaya. Various functional and life history traits were obtained from standard literatures supplemented by field observations. FRic of birds was highest in MOA, FDis in FA, whereas, FEve and FDiv were high in NF and LCA. Similarly, butterfly FRic was highest in MOA which declined along the gradient, whereas FDis was highest in LCA, and FEve and FDiv in NF. The patterns of FRic mirrored the declining pattern of butterfly taxonomic diversity (TD), whereas it contrasted with the bird TD. We observed a significant variation in various life history traits of birds and butterflies across agroecosystem forest gradient. We found environmental filtering of functional traits of both birds and butterflies, and consequently, the associated ES along the agroecosystems-forest gradient. The IFS of Eastern Himalaya can sustain not only high TD but also high FD, functional composition and associated ES, and, therefore, immediate conservation policy framework aids in biodiversity conservation as well as increases crop productivity.

### Potentials and limitations for mapping tree assemblage gradients in agroforestry landscapes with satellite remote sensing

\*Sam Harrison, University of Edinburgh, United Kingdom

Casey Ryan, University of Edinburgh, United Kingdom

Rhett Harrison, World Agroforestry Centre (ICRAF), Zambia

Trees on farms are a critical tool in managing agriculture to support biodiverse landscapes and will play an important part in complementing protected areas as a means of reaching national biodiversity targets. To understand the state and changes in biodiversity in these landscapes, it is important that they can be monitored in a consistent and timely manner. However, efficient wide-scale monitoring methods are lacking, and more focus is needed on how satellite data can be used for the landscape level analyses needed to monitor biodiversity. As an Essential Biodiversity Variable, modelling and monitoring community composition is critical for understanding change in biodiversity and monitoring the impacts of interventions. This study tests a novel approach to map gradual changes in tree species assemblages in complex agroforestry landscapes. Using a combination of optical and radar remote sensing data alongside biophysical spatial data layers, axes from an ordination of sample plot data are modelled spatially. The method is applied to three different tropical agricultural landscapes in Uganda, Rwanda and Honduras, testing applicability in multiple contexts. The results show that in these mosaic landscapes, gradients of tree species assemblages could be accurately mapped using freely accessible remote sensing data, with optical and radar bands being important predictor variables in the model alongside biophysical data. Validation showed mean model RMSE per site between 11-14% showing good model performance. Limitations to the methods are discussed. The promising results confirm that a fusion of satellite data may allow more detailed spatial

assessments of community composition for understanding biodiversity in agricultural landscapes than were previously carried out by satellite data and may be useful in monitoring agroforestry systems for biodiversity.

Room 304A/B

## D1. Transitioning to a Viable Climate

Soil organic carbon variation after 23 years of agroforestry on three paired watersheds under a corn-soybean rotation

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Unsustainable agricultural practices deplete soil organic carbon (SOC), affecting the environment and land productivity. Agroforestry (AF) practices are believed to sequester carbon (C) on agricultural watersheds; however, long-term studies evaluating AF influence on C sequestration are limited. This study evaluated the long-term effects of AF buffers (AFB), grass buffers (GB), row crop (RC) area, and grassed waterways (GWW) on SOC in three paired watersheds under on a corn (*Zea mays* L.)-soybean (*Glycine Max* L. Merr.) rotation. Grid soil samples from 86 locations were collected in 10 transects for 0-10 cm and 10-20 cm depths and determined SOC. The SOC% among managements increased following the pattern RC < AFB < GB < GWW. The SOC% in the AFB, GB, and GW areas was 2.3 %, 12.6 %, and 17.3 % greater than in the RC area. The SOC% among landscape positions increased from summit to foot slope (foot slope > backslope > summit). From 2000 to 2020, the average SOC% in the first 10 cm in the AFB and GWW increased by 17% and 9%, respectively. The effect of landscape position on soil C was consistent with previous studies on these watersheds; the greater SOC% was found in the foot slope positions. The average SOC% among management practices had from 18 to 43% more SOC% in the top 10 cm than in the subsequent 10 cm. The average SOC% among soil types followed the pattern Armstrong loam < Putnam silt loam < Kilwinning silt loam, retaining more SOC the soils with greater clay content. This study indicates that foot slope positions store more SOC than upper positions. Additionally, establishing AFB and GB within agricultural fields increases the SOC% compared to RC areas and builds up SOC% over time.

Non-growing season greenhouse gas emissions in unfertilized perennial bioenergy crops on low productive agricultural land in southern Ontario, Canada

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There is a knowledge gap on greenhouse gas (GHG) emission from perennial bioenergy crops on low productive agricultural land during the non-growing season. Furthermore, only a few studies have quantified GHG emission during the winter months, but these studies have mostly taken place in annual fertilized row crop systems. To date, no study has evaluated non-growing season GHG emission in unfertilized perennial bioenergy crops on low productive agricultural lands. Our

objective was to quantify the non-growing season N<sub>2</sub>O and CO<sub>2</sub> emission in unfertilized switchgrass (*Panicum virgatum* var. Cave-in-Rock), miscanthus (*Miscanthus giganteus* var. Nagara), and willow (*Salix miyabeana* clone SX67) on low productive agricultural land in southern Ontario, Canada. The crops were established in 2009 and have received no fertilizer since 2017. Bi-weekly sampling and measurements of CO<sub>2</sub> and N<sub>2</sub>O began in October 2019 and are ongoing. We present results from our first non-growing season sampling from November 2019 to April 2020. We found higher ( $p < 0.05$ ) N<sub>2</sub>O-N emissions from switchgrass ( $2.40 \times 10^{-5} \mu\text{g N}_2\text{O-N m}^{-2} \text{ h}^{-1}$ ) than from miscanthus ( $-1.59 \times 10^{-2} \mu\text{g N}_2\text{O-N m}^{-2} \text{ h}^{-1}$ ) and willow ( $-1.77 \times 10^{-2} \mu\text{g N}_2\text{O-N m}^{-2} \text{ h}^{-1}$ ). CO<sub>2</sub>-C emissions were highest ( $p < 0.05$ ) from willow ( $6.08 \times 10^{-5} \text{ mg CO}_2\text{-C m}^{-2} \text{ h}^{-1}$ ) followed by miscanthus ( $5.09 \times 10^{-5} \text{ mg CO}_2\text{-C m}^{-2} \text{ h}^{-1}$ ) and were lowest in switchgrass ( $4.48 \times 10^{-5} \mu\text{g CO}_2\text{-C m}^{-2} \text{ h}^{-1}$ ). Our results showed that miscanthus and willow were N<sub>2</sub>O-N sinks, whereas switchgrass was a N<sub>2</sub>O-N source during the non-growing season.

### Soil organic carbon sequestration in temperate agroforestry systems A meta-analysis

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Soil organic carbon (SOC) sequestration by improved agricultural practices is an acclaimed strategy to combat climate change. Nevertheless, the aim of increasing of SOC encounters limitations, e.g. with regards to permanence of carbon storage or leakage effects in food production. Agroforestry systems (AFS) are a promising land use option that can sequester substantial amounts of SOC while addressing these challenges. With a focus on temperate climate zones worldwide, available information on SOC in AFS was reviewed to determine their SOC sequestration potential and respective controlling factors. From a total of 61 observations, SOC sequestration rates in soils of AFS were derived for alley cropping systems ( $n = 25$ ), hedgerows ( $n = 26$ ) and silvopastoral systems ( $n = 10$ ). The results showed that AFS have a potential for substantial SOC sequestration in temperate climates. SOC stocks were higher in the topsoil (0–20 cm) than in the control in more than 70% of the observations, and higher within the subsoil (20–40 cm) for 81% of all observations, albeit large variation in the data. The mean SOC sequestration rates were slightly higher at 0–20 cm ( $0.21 \pm 0.79 \text{ t ha}^{-1} \text{ yr}^{-1}$ ) compared to 20–40 cm soil depth ( $0.15 \pm 0.26 \text{ t ha}^{-1} \text{ yr}^{-1}$ ). Hedgerows revealed highest SOC sequestration rates in topsoils and subsoils ( $0.32 \pm 0.26$  and  $0.28 \pm 0.15 \text{ t ha}^{-1} \text{ yr}^{-1}$ , respectively), followed by alley cropping systems ( $0.26 \pm 1.15$  and  $0.23 \pm 0.25 \text{ t ha}^{-1} \text{ yr}^{-1}$ ) and silvopastoral systems showing a slight mean SOC loss ( $-0.17 \pm 0.50$  and  $-0.03 \pm 0.26 \text{ t ha}^{-1} \text{ yr}^{-1}$ ). Moreover, SOC sequestration rates tended to be higher for AFS with broadleaf tree species compared to coniferous species. We conclude that temperate AFS sequester significant amounts of SOC in topsoils and subsoils and represent one of the most promising agricultural measures for climate change mitigation and adaptation.

**Does alley cropping agroforestry with nitrogen-fixing species mitigate greenhouse gas emissions?**

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Land use change and agriculture currently account for 24% of global greenhouse gas emissions, a contribution that could reach 40% by 2050. There is therefore a need to reduce the impacts of agriculture on the global climate. Agroforestry, through the intercropping of trees, is one option to reduce greenhouse gas emissions (Hawken, 2017). The presence of trees could indeed have an impact on methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions by altering soil water content, light intensity reaching the soil, temperature, organic matter quality and quantity, etc. The presence of nitrogen-fixing plants could also influence these emissions by modifying the form and the amount of nitrogen available for microbes and thus increasing nitrification/denitrification processes. Our objective was to determine the influence of land use (agroforestry systems, grass- or clover-ley systems or forest plantations) and the presence of N-fixing species (trees or crops) on net N<sub>2</sub>O and CH<sub>4</sub> fluxes and their dynamics, in relation with plant phenology and seasonal climate variations. This experiment was conducted near Nancy (northeastern France), on a clay soil subject to flooding episodes. The experimental plots were planted in 2014 and consisted of 7 treatments: 2 agroforestry systems (grass-ley (ryegrass and fescue) intercropped with alder trees and clover ley intercropped with poplar trees), 2 cropping systems (pure clover ley and grass ley) and 3 forest plantations (poplar and alder monoculture and a 50% mixture of these 2 species). N<sub>2</sub>O and CH<sub>4</sub> fluxes were measured in each treatment, using 6 automated soil chambers per treatment. Each chamber was measured every 10.5 hours. Initial results suggest that the presence of N-fixing species has a greater impact on CH<sub>4</sub> and N<sub>2</sub>O net fluxes than land use. But these results need to be confirmed by analyzing the seasonal dynamics of these fluxes in relation to plant phenology and seasonal climate variations.

**Farmer's video: agroforestry in France**

Room 301B

**H1. Transitioning to a Viable Development**

We do it together: exploring gender jointness in agroforestry decision-making and management in Eastern Rwanda

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Studies focusing on gender issues in agroforestry tend to observe men and women roles as separated and non-overlapping, but this dichotomous portrait tends to ignore the various spheres of collaboration between men and women within agroforestry systems, areas of collaboration on which gender-transformative approaches could build upon to reach greater equality. We conducted a survey in the Eastern Province of Rwanda on the nature and level of jointness between men and women in agroforestry systems. A total of 426 randomly selected households from seven districts were surveyed. Questions captured the household socio-economic profile, agroforestry system description, and gender roles in decision-making and management. Unexpectedly, decisions on agroforestry systems were mainly made by women (37.2%) and men and women jointly (17.1%), whereas decision-making was a men-only role in 45.7% of the households. However, this proportion rose to 72.4% in households headed by men, and the same phenomenon was observed in women-led households. Almost a third of the households (31.3%) reported joint tree management, which took two main forms: a gendered, but complementary, division of labor, and a gender-undifferentiated labor division. Tree climbing activities, pest control (men) and weeding (women) were reported as very gender-specific activities even in jointly managed systems, whereas most fruit tree management tasks, tree product sales and control over sale profits showed greater gender flexibility. The gender division of the decision-making process revealed highly correlated to the gender division of tree management, suggesting that these processes influence each other or are similarly influenced by a more structural factor. This first assessment of gender jointness in agroforestry systems in eastern Rwanda sets the table for further investigations on the specific intra-household gender dynamics surrounding agroforestry system management and tends to support the assumption that gender-sensitive and transformative initiatives should adapt to the various shades of grey of gender roles in agroforestry systems.

### Serious games as a way to foster social learning of local actors and researchers towards sustainable agroforestry management

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To better understand the ways farmers interact with trees is key to any action-oriented research process aiming at supporting sustainable agroforestry management. Agroforestry systems are particularly complex agricultural systems involving diverse activities as well as covering a large biological diversity. Supporting the development of sustainable agroforestry systems hence requires specific tools for the exchanges of knowledge and discussion between the different actors, such as farmers, scholars, and extension workers. Serious games are commonly used either for collecting information and data (games for research) or for education and training (games for knowledge transfer). Using games to trigger and facilitate transformative changes represents a third way that has been promoted by specific participatory modelling approaches such as companion modelling. The game serves as an intermediate object allowing exchanges of viewpoints among participants. It builds on reality in a stylized form so that each user can find ways to project features of the socio-



ecosystem that make sense for her/him. In contrast to the "expert system" vision where the tool is supposed to provide elements for selecting the best decision, here the game seeks rather to encourage exchanges between participants so as to share points of view and opinions on the functioning of the system represented. Finding a good balance to represent complex agroforestry systems with multiple activities and a high biological diversity while keeping this representation simple and easy to catch for participants is particularly challenging. In this communication, we describe and compare two serious games on agroforestry systems in the Brazilian Amazon and in Madagascar. Despite the specificities of both contexts, common mechanisms have been identified and formalised. We discuss the generic scope of these mechanisms and describe the outline of an "Agroforestry Systems Modelling Toolkit" that could be used in a wide variety of contexts.

### Participatory training approach of sharing knowledge and research results for better adoption of organic cocoa agroforestry systems

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Agroforestry systems offer many benefits, such as diversifying incomes and reducing input costs. However, planning and managing diversified systems is knowledge intensive, and needs constant observation and adaptation to specific contexts by the farmers. Therefore, sharing knowledge between farmers, technicians and researchers critical for adoption of agroforestry systems that fit the respective situation and objectives. The dynamic agroforestry community has developed some principles that can be applied for regenerating degraded land with agroforestry systems by combining a variety of species, focussing on diversity and synergies instead of simplification and competition. These concepts, together with practical experiences, and research results are a complex set of information to be complemented with local knowledge of farmers (e.g. on species' use, available resources, local markets). Here we share experiences from elaborating training materials and conducting a training of trainers based on research findings on cocoa agroforestry and practical experiences from working with dynamic agroforestry systems and organic cocoa for more than 25 years. We used a set of training materials and methods for awareness raising for the environmental and social benefits of agroforestry systems, for example simplified research methods like infiltration measurements. Some practical visualizations e.g. for erosion on surfaces after slash-and-burn vs. slash-and-mulch, or dry run exercise for the installation and development of dynamic agroforestry plots. These methods help to understand processes that are happening on larger spatial or temporal scale. Field visits to research plots as well as farmers fields and discussions based on associated data were central. In conclusion, sharing of scientific results combined with practical and visual experiences give technicians the confidence to multiply the experiences with their farmers. While demoplots are crucial for working with farmers, additional videos describing the design and management of agroforestry systems, farmers' testimonials, and some research results directly from the field can be helpful.

### Territorial strategies implementation for a consistent development of agro-silvopasture management

\*Jacopo Goracci, Farmers' Representative, Italy

Room 204A

## J1. Which Agroforestry for Arid Climates?

Agroforestry innovations in dryland area of Africa: results of 40 years of research-action in North Cameroon and Dallol Dosso in Niger

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Method: Reaching the end of his career, R. Peltier presents a brief balance sheet of the action-research activities he has carried out with many colleagues. Results: The greatest failure was the dissemination of *Acacia senegal* fallows. Although very successful on Cameroonian research stations (at 15 years, production of 1200 kg/ha of gum and 40 m<sup>3</sup>/ha of wood-energy, improvement of the CEC, C, N & pH in the soil, doubling of maize production and tripling of cotton production compared to continuous cultivation), the practice was rarely adopted by farmers due to the failure to set up income-generating gum arabic value chains (organic or fair trade). Mediocre results (good successes but very localised) were obtained in planting live-fences and densifying trees on anti-erosion strips by sowing (*Borassus aethiopum*), planting (neem, various acacias) and Assisted Natural Regeneration (ANR) with various local species, including Combretaceae, Baobab, Shea-tree. The same applies to the planting of local and exotic fruit trees in orchards and wood-producing trees in farmers' micro-groves. The best results were obtained for the enrichment of parklands with *Faidherbia albida* by subsidising ANR to the tune of 0.2 USD / plant kept for 3 years, i.e. 20 USD for 100 trees/ha. This enabled over one million trees to be saved in North-Cameroon, but selection slows sharply when the subsidy is no longer available as the benefits are only perceptible in the long term. The situation is similar in Dallol Dosso in Niger. Discussion: While the clearing of wooded savannahs has increased significantly, particularly in the region of North-Cameroon (40% in 40 years), tree-densification has occurred on formerly degraded areas. Conclusion: It is clear that land tenure security, and the provision of technical assistance and subsidies, are decisive for the development of agroforestry innovations, but more socio-economic studies are needed to better understand the determinants of the restoration of degraded areas.

### Inverted phenology of *Faidherbia albida* paced with the dynamics of the water table

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*Faidherbia albida* is an emblematic species of agro-sylvo-pastoralism in African semi-arid areas. It combines inverted phenology (strong growth, N-fixation and production of highly palatable fodder during the dry season, ideal for livestock), defoliation during the rainy season (ideal for minimizing competition with crops) and use of deep resources mainly (riparian

in its natural habitat, phreatophyte in parklands, deeply rooted, avoiding drought stress, using mostly groundwater (isotopic evidence), ideal for recycling). What could drive the inverted phenology then? Past research most often sought to correlate its peculiar phenology with climate variables, but hardly considered its deep roots and phreatophyte behavior. We set up a collaborative observatory (Faidherbia-Flux ) in a Senegal parkland in 2018 and monitored the foliar phenology of 15 adult trees (LAI2000), radial growth, sap flow and wood water content (capacitive probes). We also monitored the dynamics of soil humidity (TDR profiles) and water table fluctuations (5-6 m, piezometers). Drainage did reach the water table, but its maximum level was delayed till the end of the wet season, corresponding to the time when Faidherbia emitted new leaves. 100% foliage was maintained until the end of December, concurrently with a maximum growth, sap flow and water table level. From January to July (driest period), we observed a slow decrease in the water table level, foliage and transpiration, all reaching minima by the end of July (start of the defoliated phase), but no drought stress. Interestingly, wood rehydrated till end of the rainy season (September-October). Considering such coincidences between deep hydrological (delayed rewatering), wood rehydration and phenological phases (inverted phenology), we suggest that this deeply rooted and phreatophyte species adjusts its phenology according to the water table and wood water content, shedding leaves when those levels reached minimum and bursting only when they resumed to maximum.

### Analysis of the future climatic conditions of the olive sector in the Tangier-Tetouan-Al-Hoceima region, Morocco

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Tangier-Tetouan-Al-Hoceima is one of the most fertile regions in Morocco, a country that is economically dependent on its agriculture. Climate projections for the Tangier-Tetouan-Al-Hoceima region, e.g., rising temperatures and falling rainfall, could have negative impacts on crops and may weaken the country's food security. The olive tree, a traditional Mediterranean crop, could be used in climate change resilient agroforestry systems. This study aims to predict future climatic conditions in the Tangier-Tetouan-Al-Hoceima region, and to evaluate the impacts of climate changes on photosynthetic activity and on the natural distribution of olive trees. To do so, different climate scenarios were built for the region of Tangier-Tetouan-Al-Hoceima using 52 simulations comprised in the CORDEX-Africa ensemble and using ERA5-Land reanalysis data. Five agroclimatic indicators based on temperature and precipitation were identified based on a literature review. These indicators were used to evaluate changes in the natural distribution areas of olive trees in the study region as well as the spatial variations in the exposition of photosynthetic activity disruptions and burning. Results show that the risks of slowing and stopping photosynthesis, as well as the risk of burning, could increase over the next decades. This decrease of photosynthetic activity will be even more severe as CO<sub>2</sub> emissions in the atmosphere increase. The results also show that the change in precipitation could weakly affect natural distribution areas of olive trees. In conclusion, projected climate conditions should remain compatible with olive trees cultivation in Tangier-Tetouan-Al-Hoceima region. Traditional Mediterranean agroforestry systems including olive trees could be used to limit soil erosion and to diversify farmers' income, and thus might be a promising measure of adaptation to climate change. However, a network for monitoring olive trees yield would be necessary to have a better understanding on how olive trees are resilient to climate change.

### Productivity and drought resistance of maize intercropped with *G. sepium* and pigeonpea

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Crop diversification through intercropping can enhance agroecosystem resilience to low and sporadic precipitations typical semiarid areas. We tested whether intercropping maize with *Gliciridia sepium* and/or pigeonpea improves productivity and drought resistance of maize. A split-split-plot experiment was adopted to test the effects of intercropping (maize monoculture, sole pigeonpea, maize-*Gliciridia*, maize-pigeonpea and maize-pigeonpea-*Gliciridia*), fertilizers (with and without) and rainfall (ambient and drought). Drought was induced using the above-canopy rainout shelters which intercepts 50% of the ambient rainfall. Drought reduced gravimetric soil moisture in 2019 by 12.5% without creating artificial growing conditions under shelters. Intercropping with either *G. sepium* or pigeonpea alone did not reduce grain yield compared to maize monoculture, suggesting that farmers can diversify their fields without compromising crop yields. The cropping systems by fertilizer effects on rainwater use efficiency was significant in 2020 and it was the highest when both *G. sepium* and pigeonpea were in the mixture. Maize grain yield changes due to induced drought (resistance) was affected by the interactions of fertilizer and cropping systems (Fig. 1) in 2019 ( $p < 0.0001$ ) and by the main effect of fertilizer in 2020 ( $p = 0.0202$ ). In both seasons, yield changes were the highest (low drought resistance) in cropping system with fertilizer (Fig. 1). Thus, negative changes in 2019 would reflect yield suppression due to limited moisture stress during this drought years while positive changes in 2020 is associated with improve yield under rainout shelters as precipitations in sheltered conditions (554mm) were in the optimum range for semiarid conditions. Pigeonpea yield changes due to drought was not affected by cropping seasons and fertilizer in both seasons (Fig. 1). This study suggests that crop diversification using legumes improves resource use efficiency to produce multiple products. Also appropriate selection of a drought resistant legume component, like pigeonpea, enhance agroecosystem resistance across cropping seasons.

### Agroforestry for forage production and soil improvement in desert areas of Kuwait

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Kuwait has extreme hot weather, lacks fresh water resources and fertile arable land. Forage production is very limited in Kuwait. Currently, 95% livestock feed are imported and it is the main constraint for livestock production. Although some research evaluated the performance of barley, wheat, and alfalfa involving single cropping system, no attempts were made to grow forage crops in a mixed-cropping agroforestry system. In this study, four species, *Leucaena* (*Leucaena leucocephala*), Smooth brome grass (*Bromus inermis* L.), Sorghum (*Sorghum bicolor*), and Spring Triticale (x *Triticosecale*) were grown in single and mixed cropping systems in randomized block design with three replications. The objectives of this study were to evaluate the dry matter yield of four forage species, their nutritional quality and evaluate the effects of single cropping and mixed cropping on soil nitrogen, organic matter, and microbial population diversity. Results obtained indicate significantly higher sorghum yield in single cropping than other species. Phospholipid fatty acid (PLFA) analysis of initial soil samples indicate that total microbial biomass (PLFA) is composed of about 64% undifferentiated, 28% bacteria, and 8% fungi. The

overall mean diversity index was 1.32 and not significantly different among treatments. Mycorrhizal colonization was observed in the root systems of all four species but *Leucaena* and sorghum (81% and 53%) had more root colonization under mixed cropping compared to single cropping (70% and 43%). *Leucaena* had significantly higher leaf protein content (21%) among tested species and did not have seasonal variation. Drying and soaking in water treatment significantly reduced *Leucaena* leaf tannin content. These results suggest that practice of agroforestry in very arid conditions is feasible through judicious species selection to ameliorate soil conditions, increase soil microbial diversity and produce forage crops. More long-term research is needed to determine the performance of different drought tolerant forage species and appropriate percentage crop combinations.

Farmers' Representative in this session: Emmanuel Kuh, Cameroon

Farmer's video: agroforestry in Ivory Coast

Room 301A

## K1. Which Agroforestry for Annual Crops?

Effect of windbreaks on crop yields in the U.S. Great Plains

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Windbreaks were originally promoted across the U.S. Great Plains to reduce wind erosion after the 1930's Dust Bowl. A review paper published over 30 years ago showed yield increases for a variety of crops associated with windbreaks. However, with the widespread use of no-till cropping systems and advanced crop genetics, the question is "Do windbreaks still provide a yield benefit?" This study compared data from protected and unprotected fields over multiple years across Kansas and Nebraska looking at relative soybean (*Glycine max* L.) and winter wheat (*Triticum aestivum* L.) yield differences. Farmer's pre-existing georeferenced data, generated by automated combine yield monitors, were analyzed with ArcGIS 10.7.1 to visualize windbreak interaction with crop yield. Statistics were conducted to determine if the yield in protected areas of the field was significantly different from the yield in unprotected areas. Also, yield loss was estimated from the windbreak footprint to assess if yield increases were enough to compensate for the area taken out of crop production. Results showed wheat yield presented the most positive response to windbreak effect with significant yield increases 63% of the time, with a 13% average yield increase. Soybeans showed significant yield increases 46% of the time, with a 16% average yield increase. Narrow windbreaks (1-2 tree rows, average width of 13 m) and those on the north edge of fields resulted in yield increases that compensated for the footprint of the windbreak more often than wider windbreaks on the south edges of fields.

Does the management of *Faidherbia albida* trees in Senegalese parklands affect their ecological services to improve millet sustainability?

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Josiane Seghieri, IRD, France

In central Senegal, agroforestry systems are mostly composed of *Faidherbia albida* trees scattered in pearl millet or groundnut stands, during rainy seasons. Some studies showed that Nitrogen-fixing legume tree, *F. albida*, may increase millet production and soil fertility. However, most evaluations were carried out by comparing millet plots under and far outside the tree crown influence of isolated, mature and non-pruned trees. Few studies have examined how the heterogeneity of distance between trees, tree size and pruning intensity may affect the tree services. The aim of this study was to assess how these factors may affect the services provided by the trees to millet yield and soil fertility. A network of seventy-three stations selected over five villages, was monitored over the rainy season 2019. The stations covered various combinations of tree stand density, with tree trunk size and intensity of pruning. Each station had a pair of millet plots of 16 m<sup>2</sup>, one under the canopy of a selected tree, and the other halfway between this tree and the nearest one. We showed that millet grain and straw yield, soil organic carbon, N and P Olsen were significantly higher close to trees than halfway between two trees. Multiple Linear Regression Statistics indicated that distance between tree and size had significant positive effects on most of the variables mentioned above. Unexpectedly, high tree pruning, that preserved about 30% of the potential tree canopy area, had no significant negative effects. We concluded that distance between trees and tree size may affect the extent of *F. albida* tree services to millet crop sustainability. Moreover, the current range of tree pruning intensity allowed conciliating both direct, and indirect tree provisioning and environmental services. These results may help reasoning innovative management practices for these parklands.

Maize in the heavy shade of a mature agroforestry system: wise or foolish?

\*Christian Dupraz, INRAE, France

Pablo Rostand, INRAE, France

Lydie Dufour, INRAE, France

Marie Gosme, INRAE, France

The Restinclières Agroforestry Platform is located north of Montpellier city in the South of France. It is one of the oldest European agroforestry experiments with continuous monitoring since tree plantation in 1995. Alley-cropping with several tree and crop species is monitored, including monocropping and pure forestry controls. High measured relative yields of winter crops (durum wheat, barley, pea, rape) in-between hybrid walnut tree rows were decisive in convincing many European farmers to adopt agroforestry. For the first time in 2021 a summer crop (Maize, cv Distinxxion) was monitored in the walnut trees alley-cropping system. Monocropping controls were available and the experiment was replicated in two plots with different soil fertility and tree line orientation (North-South vs East-West). Three irrigation regimes were applied to maize: no irrigation, minimal and optimal irrigation. Irrigation schemes were triggered by maize wilting: as soon as some leaf wilting appeared for the optimal scheme, and when 50% of the plants were wilted for the minimal scheme. Crop

phenology, leaf area, leaf senescence, specific leaf area, rooting depth, canopy temperature, yield and yield components were recorded. The microclimate was monitored in both monocropping and agroforestry plots, and hemispherical pictures shot in June and September allowed to document the relative irradiation of maize in each plot. Maize under walnut trees displayed a delayed phenology: flowering was 1 week late, and leaf senescence was much delayed as compared to monocrops. The height (H) of the highest walnut trees was about 14 m while the distance D between tree rows was 13 m, resulting in a H/D ratio close to 1, inducing a heavy shade on the crop. Maize yield dropped drastically in such conditions to values below 25% of the monocrop control. This relative yield was even less than the relative incident radiation, suggesting that no compensation mechanisms for light limitation were at work. When the tree lines were oriented East to West, a strong gradient was observed with productive maize rows in the sunnier part of the alley (north side, i.e. south of the tree line). However, maize rows with high relative irradiation but close to tree rows suffered heavy water stress suggesting that root competition by walnut trees was strong. Tree root pruning could have improved maize yield in this mature system. Such low yields made this maize crop not profitable for the farmer. We expected that tree shade could protect the maize crop against excess heat during summer but the 2021 summer was rainy and no heat wave was recorded. In such conditions the climate protection by the trees could not be efficient. However, these results will be very useful to check if agroforestry simulation models can predict accurately the fate of heavily shaded crops and to optimize alley-cropping design to achieve crop yield sustainability.

### Distribution of root biomass of *Vitellaria paradoxa* agroforestry parkland in the northern Sudanian zone of Burkina Faso

\*Jonas Koala, Institut de l'Environnement et de Recherches Agricoles (INERA), Burkina Faso

Abdoul Kader Traore, Université Joseph Ki-Zerbo, Laboratoire Biologie et Ecologie Végétale, Burkina Faso

Josias Sanou, INERA, Burkina Faso

Brigitte Bastide, INERA, Burkina Faso

Agroforestry is identified as a system that could help mitigate climate change in sub-Saharan countries. *Vitellaria paradoxa* parks are widespread in Burkina Faso and are recognized for their socio-economic and environmental importance. The aim of this study was to evaluate distribution of root biomass in *Vitellaria paradoxa* parkland. The study was carried out in four localities in the South Sudanian zone. In each locality, 3 trees were chosen for the study. At the level of each tree, 2 pits were dug in two different areas: under crown and outside crown. A total of 24 pits were dug, ie 12 holes under crown and 12 outside crown. To minimize influence of neighboring trees, outside crown zone (Z3) was placed halfway from the second nearest tree. The roots were sampled at five depths (0-20 cm, 20-30 cm, 30-50 cm, 50-80 cm and 80-100 cm). A manual sorting was done to separate roots for each species and fine and Coarse roots. Results show that coarse roots biomass was  $5.21 \pm 0.32$  tMS ha<sup>-1</sup> under crown and  $2.18 \pm 0.32$  tMS ha<sup>-1</sup> outside the crown. For fine roots, highest biomass was found at 0-20 cm depth ( $2.06 \pm 0.12$  tMS ha<sup>-1</sup>). Under crown showed highest fine biomass ( $1.27 \pm 0.08$  tMS ha<sup>-1</sup>). Highest density of fine roots belongs to herbaceous plants (sorghum + weeds). It was  $0.79 \pm 0.09$  tMS ha<sup>-1</sup>. Large fine roots biomass of *Vitellaria paradoxa* is located in layer below that of herbaceous plants. This study confirmed previous studies which show that *Vitellaria paradoxa* parks are sustainable agroforestry systems due to low competitiveness with crops. In addition, the root biomass shows that the carbon pool of the roots is very appreciable. Good management of these systems could therefore be one of the solutions in the country's mitigation strategy.



### Effect of tree lopping intensities and organic manure on growth and yield performance of maize under Morus based agroforestry system

C. L. Thakur, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, India

Shashi Kumar M.C., Dr. Yashwant Singh Parmar University of Horticulture and Forestry, India

Dhirender Kumar, Dr Yashwant Singh Parmar University of Horticulture and Forestry, India

The present investigation was carried out at the experimental farm of Department of Silviculture and Agroforestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during the year 2018-2019. The experiment was conducted in a split plot design (4m × 2m plot size) to analyse the impact of tree lopping intensities i.e. T0 (No lopping), T1 (25% lopping) T2 (50 % lopping) and T3 (75% lopping) with four organic manures viz., S0 (No manure), S1 (FYM), S2 (Jeevamruth) and S3 (Vermicompost) on growth and yield performance of maize under morus based agroforestry system. The study revealed that both tree lopping intensity and organic manure application had a significant effect on growth and yield of maize crop. Among different lopping intensities, T3 (75% lopping) attained maximum plant height at harvest (2.06m), cob diameter (42.94 mm), number of seeds per cob (429.5), stem diameter (1.93 cm), grain yield (18.52 kg/plot and 23.03 qtl/ha), dry matter production (316.79 g/ plant), stover yield (47.95 kg/ plot and 59.62 qtl/ha) and minimum number of days taken to flowering (64.6 days). Among different organic manures, the treatment S3 (Vermicompost) attained maximum plant height at harvest (2.06 m), cob diameter (42.48 mm), number of seeds per cob (438.0), stem diameter (1.90cm), grain yield (19.69 kg/ plot and 24.52 qtl/ha), dry matter production per plant (323.55 g), stover yield (50.28 kg/ plot and 62.64 qtl/ha) and minimum number of days taken to flowering (64.3 days). The combination of T3 + S3 (75% lopping intensity + Vermicompost) resulted best for yield parameters followed by T3S1, T2S3 and T1S3 whereas, the values were minimum in T0S0. The benefit cost ratio of growing maize under morus based agroforestry system ranged from 0.7 (T0 S3) to 4.7 (T3S2). From the study, it is concluded that integrating maize with Morus alba L offers an excellent opportunity and high income generation when trees are lopped successfully at 75% lopping intensity and manure with Jeevamruth (20 liters/plot).

Room 203

### L1. Which Agroforestry for Commercial Perennial Crops and Trees?

#### Moderate C storage, weak conservation ability and the need to renew old cocoa plantations from the Talba forest pioneer front in Centre Cameroon

\*Jean-Guy Ndje Mbile, IRAD (Institut of Agricultural Research for Development), Cameroon

Stephane Saj, CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement), France

Seguy Enock, ICRAF (World Agroforestry), Cameroon

William Mala, Université de Yaounde 1, Cameroon

Jean-Michel Harmand, CIRAD, UMR Eco&Sols, Cameroon

In Cameroon, cocoa plantations of the Talba pionner front are set up after partial, yet strong, forest clearing and planted with « hybrid » cocoa trees. Previous studies showed complex relationships between preserved forest trees and cocoa yields, which need to be investigated further. In this peculiar cocoa production zone, we studied a chronosequence of 32 cocoa plantations (8 to 73 years old). We measured cocoa and associated trees diameter, height, shade tree cover and cocoa yield. We also estimated basal area and tree biomass. Talba plantations showed a low density of associated trees (32 trees.ha-1) in comparison to other production zones in the country (80 -150 trees.ha-1) and consequently a 35-55% lower carbon storage in aerial biomass (48 Mg.ha-1). The average shade cover was also low (38%) and positively linked to the basal



area of associated trees. Associated trees were preserved for timber (*Terminalia superba*) and/or for their high economic value (*Ricinus dendron heudelotii*). Introduced trees were mainly for self-consumption (*Dacryodes edulis*). Specific diversity tended to reduce until [40-60] years old. Hence, in the mid-term, these plantations would lose their already low tree species conservation value if farmers were not rapidly encouraged to keep or renew forest-preserved trees. The age of the plot and, to a much lesser extent, the shade tree cover affected negatively cocoa yield. Other canopy attributes did not affect cocoa yield. Cocoa tree density decreased significantly with plot age. The absence of a relationship between the individual cocoa tree and the plot age suggests that the yield decrease with time was mainly due to a lack of renewal of old cocoa trees through coppicing and/or new seedlings planting. The low number of multi-stem cocoa trees in our study area confirms that rejuvenation of old plantations is a challenge for the farmers towards sustainable cocoa production.

### Soil organic carbon gain potentials by commercial perennial biomass crops grown in southern Ontario, Canada

\*Sowthini Vijayakumar, University of Guelph, Canada

Amir Bazrgar, University of Guelph, Canada

Mahendra Thimmanagari, University of Guelph, Canada

Bill Deen, University of Guelph, Canada

Kimberley Schneider, University of Guelph, Canada

John Lauzon, University of Guelph, Canada

Paul Voroney, University of Guelph, Canada

Naresh Thevathasan, University of Guelph, Canada

Switchgrass [*Panicum virgatum*, (SG)] and miscanthus [*Miscanthus* spp., (Mis)] are commonly grown perennial biomass crops (PBCs) in Ontario, Canada. The scientific literature shows positive relationships between integrating PBCs and increases in soil organic carbon (SOC). Using PBCs to enhance SOC sequestration can contribute to Canada's goal to reach net-zero greenhouse gas emissions by 2050. This study compares current SOC stock (Mg C ha<sup>-1</sup>) in PBCs to that of baseline values obtained from three different locations (having similar soil type), namely, Elora (2008, fertile soil), Guelph (2009, non-fertile soil), and Burlington (2016, fertile soil). At the time of deriving baseline SOC stocks, land conversion occurred from agriculture to PBCs. Woodlots (WLs), undisturbed natural forests were used as reference SOC for maximum SOC sequestration to predict potential SOC sequestration in the future by PBCs in the same locations. Results show that SOC stocks in all PBCs and WLs were higher compared to respective baseline agriculture fields. SOC stocks in PBCs were significantly higher in Elora (SG- 92.9'3.32, Mis- 96.4'1.43) and Guelph (SG- 88.5'5.72, Mis- 87.9'6.43) over 11 years, whereas SOC stock Burlington (SG- 87.4 ' 2.91, Mis- 101.4'10.32), showed no significant difference over 4 years compared to their respective baseline agriculture fields (74.8'2.98, 59.3'1.17, 84.1'3.39) (Figure 1). All WLs had significantly higher SOC stock compared to their respective baseline agriculture fields, showing the potential for future SOC stock gain (Elora- 84.5, Guelph- 95.1, Burlington- 35.7) by PBCs. Increases in SOC stock suggest that converting marginal lands to PBCs over the long term could create additional terrestrial C sinks and benefit to soil physical, chemical and biological properties. Over 5% of Canadian arable lands are classified as Classes 3 and 4, therefore, the conversion of these unproductive agricultural lands to PBCs could significantly contribute to Canada's climate mitigation strategies.

## Integrating new indigenous truffles into the agroforestry system in Quebec Step 1: which are they ?

\*Véronique Cloutier, Université Laval, Canada

Yves Piché, Université Laval, Canada

J. André Fortin, Université Laval, Canada

Jean Bérubé, Centre de foresterie des Laurentides, Canada

Hélène Glémet, Université du Québec à Trois-Rivières, Canada

André Desrochers, Université Laval, Canada

Truffles could be an important part of an agroforestry system as their terroir flavours, gastronomy and monetary values are high. There are indigenous truffles in non-traditional truffles producing countries, but we did not develop knowledge about how and where to find them. However small mammals who developed a co-evolution with truffles to find these as food know where to find it so we analyzed their feces to know which species are present. The objective of this study was to document the consumption of hypogeous fungi (underground fructification as truffles) by small mammals and to identify indigenous truffles. To do so, small mammals as rodents were baited to acquire their feces. From these feces, the fungal DNA was meta-barcoded to study fungi in their diet. A total of 596 fecal samples were collected in five regions of the eastern Canadian boreal forest. A total of eight species of small mammals displayed hypogeous fungi consumption, with northern flying squirrels (*Glaucomys sabrinus*) and red-backed voles (*Myodes gapperi*) as the top consumers. For identification of their fungal diets, the ribosomal internal transcribed spacer (ITS) region was used. We recovered 722 taxa of Ascomycota, 429 Basidiomycota, 81 Zygomycota, 4 Chytridiomycota, 1 Glomeromycota, and 44 unidentified fungal taxa. Of these, 28 were hypogeous sequestrate fungi, which presumably are dug out by small mammals for consumption. This study enabled the discovery of new indigenous truffles species and it is applied to industry now. New research will be soon started to go further about it and to fulfill needs of the industry. This study will be presented and the applications of it in agroforestry.

## Designing innovative agroforestry systems in oil palm-dominated landscapes

\* Alain Rival, CIRAD, Indonesia

Marc Ancrenaz, HUTAN - Kinabatangan Orang-utan Conservation Programme, Malaysia

Isabelle Lackman, Kinabatangan Orang-utan Conservation Programme, , Malaysia

Mustafah Muhammad Al-Shafieq, MOPP - Melangking Oil Palm Plantation Sdn, Bhd, Malaysia

Jean-Marc Roda, CIRAD, Indonesia

Marcel Djama, CIRAD, Malaysia

Background: TRAILS stands for “climaTe Resilient lAndscapes for wlldLife conServation”. TRAILS is a multidisciplinary research project aimed at identifying innovative solutions for wildlife and people in multiple-use landscapes. Methods: Mixed-tree forests provide habitat in the context of industrial agriculture: Pioneer tree species are efficient in restoring healthy riparian forests and providing shelter for wildlife. Then small mammals, primates or disseminate seeds originating from nearby patches of natural forests and contribute to the natural cycle of forest regeneration. Biodiversity corridors contribute to climatic resilience as agroforestry systems can mitigate climate change through the sequestration of atmospheric carbon dioxide in plants and soil. Changes in GHG emissions and soil organic carbon stocks are monitored after land conversion into agroforest. Mixed plantations can also improve livelihoods: It is key to understand changes in the structure and stability of oil palm planters’ income induced by the transition from monoculture plantations towards mixed-planted systems. Objectives: To install oil-palm-based agroforestry systems: mixed planting are installed using selected oil palm seedlings and native forest tree species grown in locally-run nurseries in the study area (Sabah, Borneo Island, Malaysia); To monitor wildlife recolonization dynamics (abundance, diversity, and mobility) in areas covered with mixed-

planting, riparian corridors, and oil palms; To study the agronomic performance of oil palms: growth, development, and nutrition of palms together with fruit yields and bunch characteristics are measured; To understand key characters of climate resilience through the monitoring of bioclimatic condition of the parcels and their ability to provide environmental services; To analyze the socioeconomic impact of the transition from oil palm monospecific plantation to agroforestry systems. Conclusion: TRAILS builds on a complementary partnership, linking academic, NGOs, private and public stakeholders, thus enabling integrated approaches arising from various science fields, from agronomy and forestry to veterinary sciences while including a detailed socioeconomic approach of livelihoods.

Farmers' Representative in this session: Alberto Ke iti Opata, Brazil

Room 303B

## O1. Agroforestry - an Essential Pillar of Agroecology

Harnessing the multiple dimensions of agroforestry contributions to agroecological transitions using visual narratives

\*Edmundo Barrios, Food and Agriculture Organization of the United Nations (FAO), Italy

Francesco Ajena, Food and Agriculture Organization of the United Nations (FAO), Italy

Ronnie Brathwaite, Food and Agriculture Organization of the United Nations (FAO), Italy

The magnitude and urgency of the challenges facing agriculture and food systems demand profound modifications in different aspects of human activity to achieve real transformative change and sustainability. The disconnection between food production and consumption, and between local practices and global commitments is an important restriction to the implementation of the SDGs by limiting the capacity for alignment of single actors and collective action towards positive economic, environmental or social impacts. Successful transitions to sustainable agriculture and food systems would likely benefit from holistic and people-centred approaches that embrace a long-term vision, such as agroecology, which is increasingly acknowledged for its potential to bring about transformative changes required to meet the SDGs. Agroecology is an integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of food and agricultural systems. Recognizing that the inherent complexity of achieving sustainability is commonly seen as a deterrent to decision-making, the 194 member countries of FAO Council approved the 10 Elements of Agroecology as an analytical framework to support the design of differentiated paths for agriculture and food systems transformation. We will highlight the important contributions of agroforestry to the biodiversity, consumers, education and governance entry points and build a structured process using visual narratives that rely on the 10 Elements of Agroecology to graphically dissect prospective social-ecological transition trajectories and guide integrated policy design. Visual narratives will explore the biodiversity-nutrition-climate change nexus, the consumers-markets-health nexus and the education-youth employment-migration nexus. It will be shown that this type of structure can allow different stakeholders to articulate challenges faced, build consensus towards desired goals, use a common language when sharing information on the status of implementation, and encourage collective action and alignment towards achieving the greatest possible impact.

## Is agroforestry an effective way to diversify cropping systems to improve biodiversity and ecosystem services?

Damien Beillouin, CIRAD, France

Tamara Ben-Ari, INRAE, France

Eric Malezieux, CIRAD, France

Verena Seufert, CIRAD, Germany

David Makowski, CIRAD, France

Increasing the diversity of species in agricultural systems is expected to benefit biodiversity and enhance ecosystem services. A fast-growing literature on this subject has produced numerous qualitative and quantitative syntheses largely varying in their scope, quality, type of crop diversification considered, and indicators of ecosystem services investigated. It resulted in a fragmented evidence difficult to synthesize and analyze for most decision makers. Here, we quantified simultaneously the biodiversity, supporting, regulating and provisioning ecosystem services of five main type of crop diversification, i.e., agroforestry, associated plants, intercropping, crop rotation and cultivar mixture. In this aim, we collected and integrated the results of 5156 experiments from 95 meta-analyses, covering more than 120 crops and 85 countries. Our results show that, all crop diversification strategies considered together, significant improvement of crop yields, associated biodiversity, and several ecosystem services including water quality, pest and disease control, and soil quality are obtained compare to less diversified systems. Yet, there was substantial variability in the results for each individual ecosystem service between the different diversification strategies. Agroforestry strikes out as a particularly promising strategy compared to the 4 others; that is able to substantially increase all the ecosystem services considered in our analysis, that is, associated biodiversity (+61%, [26%, 105%]), production (+35%, [12%, 62%]), water regulation (+45%, [13%, 87%]), water quality, pest and diseases control (+59%, [38%, 82%]), and soil quality (+19%, [16%, 23%]). We detailed these performances according to the type of agroforestry systems (e.g. parkland, alley cropping, hedgerows); and identified knowledges gaps. Further investigation is of interest to study the performance of systems where several diversification strategies are combined, and the economic performance of these systems, which have so far been poorly documented in the papers identified.

## Bonn Challenge: Role of Agroforestry in meeting Global and Country Level Pledges for Forest Landscape Restoration and NDC targets

\*Vivek Saxena, Haryana Forest Development Corporation, Government of Haryana, India

Manpreet Kaur, International Union For Conservation Of Nature (IUCN), India

Bonn Challenge Pledges aim at Forest Landscape Restoration (FLR) of about 150 million hectares by 2020 and 350 million hectares by 2030 at Global level- both being landmark years in the context of beginning UN Decade of Restoration and attainment of Sustainable Development Goals (SDGs). Agroforestry is one of the very important FLR activity other than Planted Forests and Woodlots, Natural Regeneration, Silviculture, Improved Fallow, Mangrove Restoration, Watershed Protection and Erosion Control. FLR has potential of facilitating Restoration initiatives through Nature Based Solutions (NbS) as well as meeting Global and Country Level Pledges for FLR, Nationally Determined Contributions (NDCs), SDGs, Aichi Biodiversity Targets and objectives set out in Post 2020 Biodiversity Framework. India' Bonn Challenge Pledge stands at 13 million Hectares under FLR by 2020 and additional 8 million Hectares by 2030. Upscaling the Pledge by 5 million hectares during UNCCD CoP, India's Pledge of 26 million hectares is largest Pledge by any Country. Agroforestry contribution towards FLR under Bonn Challenge in India during Period 2011-2020 has been assessed through data and information collected from States. Role of ToF (Trees Outside Forests) and Agroforestry in meeting FLR and NDC commitments as well as contribution in total wood consumption has been assessed. Recommendations for upscaling Potential for Agroforestry as Mitigation as

well Adaptation option through Policy Analysis related to Agroforestry, identification of Constraints, Opportunities and Threats have been made for enhanced contribution in meeting FLR pledges, NDC Targets and other Commitments under CBD, UNCCD.

### Agroecology approach in Asian agroforestry

\*Mi Sun Park, Seoul National University, Korea, Republic of (South Korea)

The concept of agroecology has multiple dimensions such as economic, social and environmental. It is used as science, practice and social movement. Agroecology approach and agroforestry system has been developed and understood differently by culture. In France, agroecology was mainly understood as a farming practice. In Germany, agroecology has a long tradition as a scientific discipline. Brazil has a stronger emphasis on movement and agricultural practice. There are many studies on agroecology in Europe, Africa and America. However there are a few research on agroecology in Asia except China. This study has a focus on Asian agroecology and agroforestry. It aims to examine development of the concept of agroecology in Asian agroforestry through literature review and expert interviews. Asian agroforestry cases will be interpreted with the agroecological approach as science, practice and social movement. Research findings provide a better understanding of agroecology in Asia towards sustainable agroforestry.

### Toward a perennial agriculture: Building an agroforestry research program at the Savanna Institute

\*Fred Iutzi, Savanna Institute, United States

Keeffe Keeley, Savanna Institute, United States

Kevin Wolz, Savanna Institute, United States

Ecological degradation resulting from the replacement of native ecosystems with low diversity, high disturbance, high productivity annual crops creates the signature dilemma for North American agriculture today: how to produce greatly improved ecosystem services outcomes while producing ample food for people. We believe widespread agroforestry systems with productive tree crops, crop-livestock integration, habitat restoration, and intensive disturbance management are part of the way forward. The annual grain crops and cropping systems that currently dominate the landscape have been enabled by more than a century of large public and private investments in agricultural research, while tree crops and agroforestry have seen relative disinvestment. Accordingly, among several other needed inputs – including technical assistance, market development, and supportive public policy – a new emphasis on tree crop and agroforestry research is needed to unlock the full potential of agroforestry in the Midwest USA and other regions. The Savanna Institute, a nonprofit organization based in Wisconsin, and Illinois, USA, working in collaboration with university and agency researchers, farmers, agricultural and conservation organizations, and private companies, is implementing a broad-based program of research to contribute to filling this gap. Work underway includes a tree crop improvement program that characterizes plant genetic resources, performs controlled crosses, and develops improved populations; a program to quantify the benefits of agroforestry systems for carbon sequestration, water quality, and other parameters; a program to improve management techniques in crops and cropping systems; and work to integrate knowledge from these programs into spatially-explicit information tools to accelerate agroforestry adoption. Research at Savanna Institute has begun to contribute valuable knowledge and innovations to Midwestern and North American agroforestry; we anticipate that larger impacts will emerge from wider collaboration to find and exploit knowledge and capacity synergies, carry out cooperative research, and work to increase the overall resource base for agroforestry research.

*Coffee break: 3:30 to 4:00 pm*



3:30 pm, Room 400A

## Poster Session 1

All posters will be displayed in the room during all the congress. Two sessions (Monday 3:30 to 5:00 pm and Tuesday 3:00 to 4:30 pm) are also planned in the program so that authors can present their posters in-person and discuss with other participants about them.

Monday's session will be divided into 3 periods of 30 minutes each:

- The first period will be allocated to a free visit of the posters.
- In the second period, half of the authors of posters on the same theme will be divided into small groups and invited to present their poster in turn, for a period of approximately 3 minutes each, in front of the members of their group, to whom will be able to join all the other participants interested in their theme.
- The other half of authors will do the same during the third period.

During the Tuesday session, after a 30-minute free visit, the members of each of the groups will be invited to discuss their theme with each other for approximately 45 minutes as part of a cooperative creative workshop.

### Monday session

4:00 to 4:30: Group presentations #1 - Posters with ODD numbers (table p. 95)

4:30 to 5:00: Group presentations #2 - Poster with EVEN numbers (table p. 101)

These periods will be dedicated to group presentations for posters with ODD numbers during the first period (A1, A3, A5..., O5) and for posters with EVEN numbers in the second period (A2, A4,..., O8), in most cases. Presenters assigned to the same group will gather at the first poster of their group (in bold in the tables, p. 95 and 101). Presenters that are not assigned to a group visit will be invited to join the group of their choice or walk around, just as the other congress participants.

The group members will present their posters in 3-4 mins + 1 min question each, so that you visit all the posters in your group within 25 mins (time spent at each poster can thus be adjusted depending on the number of posters in your group).

At the end of the group presentations, all participants will vote for the best poster presentation using the form accessible through this link at the beginning of the session:

<https://forms.gle/DWfW9fPznz4mFJyBA>

5:00 pm, Room 202

Side Event - Success Stories of 15 years of research on coffee and cocoa conducted by the Agroforesta platform in Central America: sharing of experiences, tools and results, and testimonies from stakeholders (dP Agroforesta)

Agroforesta scientific platform on agroforestry in Latin America has been working for 15 years on the development of sustainable and efficient coffee and cocoa-based agroforestry systems. The platform's members (CIRAD, CATIE, Promecafé, Bioversity International and ICRAF) are working with production and research and development actors to improve the performance of agroforestry systems in terms of productivity and profitability, as well as their contribution to the well-being of rural populations and the preservation of the environment and natural resources. Share with us the successes of 15 years of research at this event!

by Laurène Feintrenie, CIRAD, CATIE, World Agroforestry & Philippe Vaast, CIRAD, World Agroforestry.

Language: English/Spanish (some testimonies)





6:30 pm, Room 200A/B

## Side Event - International Union of Agroforestry (IUAF) General Assembly

The International Union for Agroforestry was created in 2019 in Montpellier. The scope of IUAF is to promote agroforestry worldwide, and IUAF is particularly in charge of organizing the World Congresses on Agroforestry. Please consult the IUAF website to know more: <https://iuaf.org>. The first General Assembly of IUAF will have the following agenda:

- Welcome address,
- Activity Report by the IUAF President. Vote of approval (electronic vote),
- Election of the new board of trustees: presentation talk by the applicants, opening of the electronic vote,
- Financial Report by the IUAF treasurer. Vote of approval (electronic vote),
- Keynote speech by a charismatic figure (To be disclosed soon),
- Presentation of the scope and strategy of IUAF, open floor to IUAF members
- Closing of the electronic vote for the new board of trustees. Announcement of the results of the election of the board. The new board of trustees will meet on the spot to elect the new bureau (President, Secretary, Treasurer),
- Announcement of the received bids to host the next World Congress on Agroforestry (2025),
- Announcement of the composition of the new bureau of IUAF (President, Secretary, Treasurer),
- Closure of the General Assembly.

A meet and chat cocktail will be offered to IUAF members after the General Assembly. Reserved to IUAF members (free membership for all 5<sup>th</sup> World Congress on Agroforestry participants, if you accepted at registration).

Language: English.



Tuesday, July 19, 2022: at the Banquet

Traditional Québec music

## The Quintuor trad du terroir

The “Quintuor trad du terroir” is a music group specially formed to share with you the various forms of traditional arts of Québec. Answer songs, cuddled dances and festive instrumental pieces will be there to get you moving in the company of artists from legendary bands such as *La Bottine Souriante*, *Le Rêve du diable*, *Les Chauffeurs à pieds*, *La Galvaude*, *Le Bruit court dans la ville* and *Les Charbonniers de l'enfer*.

Get your shoes ready, it's going to swing!!!

Group members: Louis-Simon Lemieux (harmonica, guitar, violin, foot, voice), Benoît Fortier (flute, voice), André Marchand (guitar, voice, foot), Stéphanie Lépine (violin), Ghislain Jutras (câll, guimbarde).



Tuesday, July 19, 2022

8:30 am, Room 200A/B

## Plenary Session: Governance of Agroforestry Initiatives

Agroforestry is now at the heart of global strategies to mitigate climate change and combat environmental degradation. As part of the Bonn Challenge, 47 countries have pledged to restore 350 million hectares of degraded land by 2030. Whether through initiatives specifically targeting carbon sequestration to offset emissions, or projects focused on forest landscapes restoration (FLR), many actors seek to spread agroforestry systems. However, these initiatives depend on international funds and carbon finance targeting the land of farmers in low-income countries, where it is assumed that the establishment of agroforestry systems is less expensive and more compatible with farmers practices. Should we be wary of agroforestry projects resulting from international objectives and carbon finance or celebrate the advent of a new era that promises to accelerate the spread of agroforestry? How to ensure adequate governance of these initiatives which objectives and modus operandi may go against peasant systems and values? What are the real needs of peasant communities, and are they really compatible with the global goals of carbon sequestration and ecological restoration? This Session convenes various perspectives on the issue in order to promote exchanges.

The power relations of agroforestry initiatives: from reductionist technical fix to agrarian political economy transformation

Vijay Kolinjivadi, Postdoctoral researcher at the Institute of Development Policy (IOB) of the University of Antwerp

The Importance of Agroecology for Successful Agroforestry Policy and Programs

Jessica Donham, Researcher for Agroecology Europe

How forest carbon forces us to think about livelihoods

Kahlil Baker, Co-fonder and executive director of Taking Root

Agroforestry in the Program of Payment for Environmental Services, the experience of Costa Rica

Gilmar Navarrete Chacon, Director of Environmental Services of the National Forest Financing Fund in Costa Rica

How ACORN unlocks access to fair & transparent carbon payments for smallholder agroforestry farmers worldwide

Emma van de Ven, Strategy Lead for ACORN, Rabobank.

*Coffee break: 10:00 to 10:30 am*

Workshops in French only:

## Développement d'une agroforesterie pour le Québec

La transition des systèmes de productions agricoles vers des systèmes plus écologiques est amorcée. Pour accélérer le mouvement, l'agroforesterie est proposée au Québec, comme en Europe et aux États-Unis, afin de valoriser les effets bénéfiques des arbres pour la résilience des agroécosystèmes en favorisant notamment la biodiversité, la santé des sols, l'adaptation aux changements climatiques et leur atténuation.

Au travers de 3 ateliers, des représentants.es d'organisations œuvrant en agroforesterie au Québec, en France et aux États-Unis présenteront un portrait des moyens qu'ils mettent en œuvre pour appuyer le développement de l'agroforesterie et livreront leur vision de ce qui importe le plus et de ce qui doit être amélioré. L'ensemble des propos est de nature à nous inspirer, ici au Québec, pour planifier de nouvelles initiatives de développement de l'agroforesterie.

Chaque atelier aborde des enjeux clés associés au développement de l'agroforesterie et est d'une durée de 1h30, composé de 3 conférences d'experts.es et suivies de 30 minutes d'échanges avec la salle. Venez discuter avec nous et influencer les pensées pour une plus grande reconnaissance et adoption des pratiques d'agroforesterie !

Salle 202

10h30-12h00

### Atelier 1 : Modes d'appuis aux producteurs.trices

Initiatives agricoles et soutiens agroenvironnementaux favorables à l'adoption de systèmes agroforestiers au Québec

Ghalia Chahine, PhD. – Coordinatrice à l'environnement de la Direction des recherches et des politiques agricoles (DREPA) de l'Union des Producteurs Agricoles du Québec, Québec

L'agroforesterie : une aventure nécessairement collective... et globale

Alexandre Parizel, Ing. Agr. – Coordinateur du pôle R&D de l'Association Française d'Agroforesterie, France

Au menu des agriculteurs américains : spaghetti et soupe alphabet

Myriam Lafrenière-Landry, Agr. MSc. – Coordinatrice du « Muchakinock Creek Watershed Coordinator », États-Unis

13h30-15h00

## Atelier 2 : Les actions d'organisations promotionnelles de l'agroforesterie

Retour d'expériences du RMT Agroforesteries, un réseau de partenaires de la recherche, du développement et de la formation pour soutenir le développement de l'agroforesterie en France

Léa Lemoine, Ing. Agr. – Coordinatrice du Réseau Mixte Technologique agroforesterie (RMT agroforesterie), France

Catalyzing wider application of agroforestry in the US North-Central region: the work of the Savanna Institute

Keefe Keeley, PhD – Co-Executive Director, Savanna Institute, États-Unis

Développer une agroforesterie pour le Québec: les dix travaux du groupe d'experts du CRAAQ

Alain Cogliastro, PhD. – Président du comité Agroforesterie du Centre de Référence en Agriculture et Agroalimentaire du Québec-(CRAAQ) et Chercheur associé à l'Institut de recherche en biologie végétale (IRBV), Québec

15h30-17h00

## Atelier 3 : Témoignage et outils de développement

Témoignage d'un producteur du Québec: l'intégration de l'agroforesterie dans sa pratique

Mathieu Bisson – Producteur laitier, porcin et de grandes cultures de la Beauce, Québec

Développement d'un simulateur économique pour évaluer la rentabilité d'aménagements agroforestiers dans l'est du Canada

André Vézina, M.Sc. – expert en agroforesterie, Biopterre, Québec & Frederic Lebel, M.Sc. – professeur/chercheur, Institut de technologie bioalimentaire du Québec et Biopterre, Québec

Accélérer l'adoption de l'agroforesterie par la technologie et le capital

Harry Greene, MBA – Chief Investment Officer & Co-Founder at Propagate Ventures, États-Unis

10:30 am

## Parallel Sessions

Room 202

**Workshop Québec: see page 43**

Room 200A/B

## C2. Transitioning to Biodiversity

**Transforming landscapes for greater biodiversity through the establishment of Forest Gardens****\*Andrew Zacharias, Trees for the Future, United States**

Olivier Allongue, Trees for the Future, United States

Elizabeth Moore, Trees for the Future, United States

Background: The Forest Garden model has been the core methodology of Trees for the Future's training programs with smallholder farmers implemented with 35,000 farmers in East and West Africa over the last 5 years. Forest Gardens are an excellent model for improving biodiversity due to their multistory cropping filling 7 layers and permanent perennial crops that provide green cover on the land throughout the year. Over 10,000 trees are planted in a 1-2 acre field and farmers practice Integrated Pest Management to reduce pesticide use. In the 4-year program, most farmers move from growing 1 food crop on their field to 5 food crops and 7 marketable products by year 3. Objectives: This development' program-based' presentation will provide an overview of the Forest Garden Model and structure, frequent species used, and present the opportunity for building biodiversity habitat through agroforestry with smallholder farmers. This model integrates key biodiversity goals such as the inclusion of indigenous species, the reduced use of pesticides and harmful chemicals that reduce biodiversity in agricultural systems and presents a method for integrating biodiversity and agroforestry models at scale and at a landscape level. Methods: Annual surveys with 5,000 program farmers in Senegal recording trees planted and products grown and drone footage are the two primary methods used. Results: Results will include tree-planting, food crop and marketable products data from program annual surveys alongside drone images that show comparable tree cover in villages with Forest Gardens. Discussion: Discussion will include opportunities and challenges with using indigenous species, the challenge of IPM, and the potential for community-level land use restoration combatting fragmentation and creating corridors using West Africa and the Great Green Wall Project as an example. Conclusion: Forest Gardens offer an excellent opportunity for transforming landscapes for greater biodiversity habitat.

### Linear features in cattle ranches in Catacamas Honduras: existence and opportunities to increase tree cover

Eduardo Somarriba, CATIE, Costa Rica

**\*Arlene Sampson, CATIE, Costa Rica**

Edwin García, CATIE, Honduras

Marta Suber, World Agroforestry, Peru

Norvin Sepulveda, CATIE, Nicaragua

Felipe Peguero, CATIE, Costa Rica

Trees are ubiquitous elements in agricultural landscapes in the tropics. In Honduras cattle ranching and pasturelands cover approximately 50% of all the county's agricultural land. Therefore, targeting cattle ranching to increase tree cover and support the provision of environmental services is key specially in the tropics. Scattered trees and linear features, mainly live fences, and riparian forests, are a common feature in pastureland. Typically, cattle ranchers tolerate around 20% of tree canopy cover in their farms. We inventoried, in 25000 ha, the linear features in Catacamas pastureland, and we found approximately 40% (654 km) of these structures are dead fences and 60% (1076 km) are composed of live fences dominated by a few occurring at a linear density of 69.2 m/ha of pastureland. We argued that in this landscape there is an opportunity to increase the linear density of live fences as a pathway to intensify (fencing is fundamental in rotational grazing to maximize animal productivity) ranching activities, diversify family incomes and support biodiversity conservation and carbon sequestration targets. We devised three scenarios that would potentially maximize cattle productivity and the multi-functionality of the live fences. The first scenario is the establishment of simple live fences composed of service trees (*Gliricidia sepium*, *Bursera simaruba*, 400 trees/km) to substitute existing dead fences. The second scenario includes different tree products (i.e., timber, fodder) and services, shade for cattle, and carbon sequestration. This will be possible by planting and managing mixed-species live fences (service and timber trees) with 565 trees/km within pasturelands. The third scenario will support habitat for biodiversity (habitat and food) by establishing multifunctional live fences (service, fruit, and timber trees) at a density of 525 trees/km) strategically placed across the landscape. Live fences are the preferred approach by landowners to include trees in their lands and are aligned with national priorities for sustainable cattle ranching.

### Better connectivity of the natural environment using agroforestry as ecological restoration in intensive agricultural zones of Southern Québec, Canada

**\*Ariane Breault, Horizon-Nature Bas-Saint-Laurent, Canada**

Mariève Lafontaine-Messier, Nature-Action Québec, Canada

Intensive agriculture is contributing to the loss of natural habitats and their fragmentation in the Montérégie region, located in the south of the province of Québec, Canada. While the area is one of the province's richest in biodiversity, anthropogenic pressures linked to agro-industrial production methods and urbanization have important repercussions on its ecosystems, whose biodiversity is threatened by the fragmentation of natural habitats caused by the difficult cohabitation of present land uses. Thus, a study was carried out in order to analyze the efforts made by various regional actors to conserve and restore ecological connectivity, especially those of Nature-Action Québec, whose interventions were used as a case study. The possible contribution of agroforestry systems for achieving these objectives was then evaluated. Agroforestry represents a solution to the issue of fragmentation through the creation of ecological networks of complex plant structures connecting residual natural habitats to each other in the agricultural landscape matrix. Linear agroforestry systems such as riparian buffers, shelterbelts, windbreaks, and tree-based intercropping systems offer corridors for the dispersal of various animals and plants. The establishment of such agroforestry systems throughout the regional agricultural territory should be

integrated in the Agricultural Zone Development Plans (PDZA), which aim to promote the sustainable development of agricultural activities, as well as in regional development plans, to promote structural connectivity and restore functional connectivity. However, the design and the implementation of agroforestry corridors in the Montérégie territory depends on the political will of the provincial government to support them through public agroforestry policies and programs.

### Seed and seedling systems for indigenous trees in refugee landscapes

\*John Osidi, World Agroforestry ICRAF, Kenya

Cathy Watson, World Agroforestry ICRAF, Kenya

\*Ann Degrande, CIFOR-ICRAF, Cameroon

**Introduction.** Uganda hosts over 1 million refugees who need trees for fuel and building materials. This fuels deforestation and conflict for natural resources. Refugees from South Sudan and DR Congo, in particular, are settled next to forests and in savanna woodlands rich in endemic and threatened species. Many humanitarian NGOs try to distribute seedlings and reduce demand for firewood with energy conserving stoves. However, biodiversity and tree diversity are rarely considered. **Significance.** Refugee landscapes need ecosystem restoration through agroforestry, reforestation, riparian revegetation and FMNR. Most refugee programmes, however, focus on exotic trees. Inclusion of indigenous species is rare. Lack of seed is one obstacle, Uganda has only one centralized tree seed source, skewing tree programmes in displacement settings towards a few exotics such as Neem and Teak for which seed is available. **Methodology.** World Agroforestry (ICRAF) has worked in two refugee settlements since 2018. It experienced challenges collecting seed and promoting indigenous trees to the refugee and host populations. In 2021 it decided to take a botanical approach and explore which trees were medicinal or had other prized qualities. Its staff were retrained along Millenium Seed Bank guidelines and now value natural vegetation and are better equipped to raise indigenous species and convey their « plantability » to refugee and host families. **Results and conclusion.** Results include the raising of hitherto « wild » trees like Ziziphus species and the highly medicinal Sterculia africana. A living hedge of indigenous species and seed stands are under establishment. Seed collection and banking are ongoing with a focus on indigenous trees for multiplication, production and genetic conservation.

### Diversity of trees on farms and associated biodiversity in the Gishwati landscape, Rwanda

Elisée Bahati Ntawuhiganayo, World Agroforestry, Rwanda

\*Athanase Mukuralinda, World Agroforestry, Rwanda

Vedaste Minani, World Agroforestry, Rwanda

Elie Sinayitutse, University of Rwanda, Rwanda

Venuste Nsengimana, University of Rwanda, Rwanda

Makui Parmutia, World Agroforestry, Kenya

Jean Claude Bambe, World Agroforestry, Rwanda

Rhett Harrison, World Agroforestry Centre (ICRAF), Zambia

Trees on farms are key features that not only improve productivity and livelihoods, but also enhance biodiversity. Farmland biodiversity has not received sufficient attention in conservation efforts and reporting due to lack of research-based evidence. We assessed tree diversity and associated diversity of birds and arthropods in agricultural landscape of Gishwati, Rwanda. Trees on Farm Biodiversity Assessment Tool was used to collect tree, bird, and arthropod data in 115 circular plots of 0.5 – 1 ha, comprising of plantation, natural forest, rangeland, and cropland. Tree height and diameter were measured,



aural and visual bird observations were recorded, and colored pitfall traps were used to collect arthropods. Seventy-six tree species from 52 families, including 52.6% indigenous, were observed. One hundred and sixty-three bird species and arthropods from 42 families were observed. More than 60 tree species were observed in the 58 cropland plots. There was a positive correlation between trees on farms species richness and bird species richness in the landscape. Of the bird species observed in farmland, *Gyps africanus* is critically endangered and *Aquila nipalensis* is endangered. In the farmland, arthropods that were recorded belong mainly to predators (36 families) and herbivores (39 families). The incorporation of trees on farms has been proven to be a biodiversity-friendly land-use practice that should be promoted and monitored. This study's novel tool will help to quantify the contribution of trees on farms to climate change adaptation, forest landscape restoration and biodiversity conservation.

Room 304A/B

## D2. Transitioning to a Viable Climate

Toward local estimation of the impacts of agroforestry on soil organic carbon and agricultural production in Sub-Saharan Africa

\*Damien Beillouin, CIRAD, France

Rémi Prudhomme, CIRAD, France

Linxian Wu, CIRAD, France

The potential of agroforestry to sequester carbon and increase yield scale is still largely uncertain at the global scale (e.g., between 1.0 to 7.4 t C ha<sup>-1</sup>y<sup>-1</sup> in soil...), and local precise estimations remain scarce. A main difficulty is the size and completeness of current database on the subject. For example, Kuyah et al., 2019 identified only 61 and 73 papers on Agroforestry for yield and soil organic carbon (SOC) in sub-Saharan Africa. In fact, most of the meta-analyses despite the aim to be systematic gather only a small part of total available evidence. Here, we produced the largest database on these subjects by collating all existing meta-analyses in sub-saharan Africa and complete it with a comprehensive systematic review. Our database of more than 270 primary studies covering 22 countries contains more than 3500 paired-comparison between agroforestry and non agroforestry systems, with details of species cultivated, pedo-climatic conditions and agricultural practices. We applied machine learning algorithms to explore effects of local moderators on SOC and yields, and thus provide precise local estimation of the potential of agroforestry. We confirm that, overall, agroforestry had a positive effect on both yield and carbon sequestration, with an average increase of about 70% and 20% respectively. We produce estimates of the potential SOC sequestration potential and yields for the various type of agroforestry systems (e.g. alley cropping, parkland...) in the different agro-ecological zones (AEZ). We also observed that day-to-night temperatures, Soil moisture at the end of the growing season and Temperature Annual Range were main determinant of the performance of agroforestry systems. Our results will allow to map local performance of agroforestry and thus provide guidance for local decision makers.

### Aggregate carbon dynamics and microbial status in different agroforestry systems

\*Aiswarya Soji Joseph, College of Climate Change and Environment Science, Kerala Agricultural University, India

Kunhamu Tk, Kerala Agricultural University, India

The role of agroforestry in climate change mitigation by trapping greenhouse gases especially carbon dioxide has been known for a long time. Trees which store carbon in the soil and biomass are the controlling factor. A crucial role in carbon and nutrient dynamics is shared by the different aggregates present in the soil. But it still remains as an unconsidered factor. The different aggregates present in the soil vary considerably in terms of their storage potential, stability and longevity. The different aggregates were fractionated by wet sieving and were analysed for carbon and nutrients. The quantity of nutrients stored were influenced by the diversity of tree species, type of soil, extent of root system etc. The usual trend that could be seen in woody ecosystems is an increasing storage potential with decreasing aggregate size. This substantiates the importance of the least found clay particles in carbon storage which in turn helps in climate change mitigation. Another factor complicating the carbon and nutrient dynamics in the soil is the microbes. These which release the nutrients into the soil also influences the aggregation. Analysing the population of microbes in different agroforestry systems also concluded that the presence of deep-rooted systems and higher species diversity promotes and provides the microbial population in the soil. These observations proved the importance of increasing agroforestry systems in carbon sequestration and promoting microbial growth.

### Not all shade is alike: Understanding shade and its impact on microclimate in optimising coffee agroforestry systems

\*Sigrun Wagner, Manchester Metropolitan University, United Kingdom

Richard Preziosi, University of Plymouth, United Kingdom

Agricultural production is under threat from climate change, especially *Coffea arabica*, a rather climate sensitive plant. Maintaining optimal yield and quality is of economic importance for producer countries; this requires effective strategies for adaptation to climate change. Integration of shade trees in coffee production systems is suggested as a possible approach, as trees may modify local microclimate, protecting coffee plants from extreme weather events. The specifics of how shade trees alter local daily temperatures has not been explored, with existing studies often only comparing shaded and unshaded systems. To improve understanding of the effect of shading on microclimate in different coffee production systems at Mt. Kilimanjaro, we surveyed and analysed multiple aspects of shade and monitored microclimate in 94 plots across a gradient of shade densities over two years. Shade components consist of shade density (determined from hemispherical photos), the proportion of number of gaps, tree density, mean tree diameter at breast height (dbh), and distance to the closest tree. Banana density, mean banana dbh, and shade exclusively from trees (determined from transect maps) were measured as well. We investigated the effect of these shade components on different aspects of microclimate, including daily maximum temperature and mean night temperature. This study highlights the importance of analysing multiple shade components rather than focusing only on shade and/or tree density. Investigating a shade gradient rather than simply comparing shaded and unshaded systems gives a more comprehensive understanding of sustainable strategies for system optimisation for the future. Our results demonstrate that inclusion of shade trees in coffee production systems is a potential adaptation strategy to climate change at Mt. Kilimanjaro, as they can reduce maximum day temperatures, without jeopardising low nocturnal temperatures, which are important for coffee development.

### Assessment of wheat productivity and soil nutrient status using *Populus deltoides* windbreak based agroforestry as climate resilient system

\*Chhavi Sirohi, Department of Forestry, CCS Haryana Agricultural University, India

Parvinder Kumar, KVK, Karnal, CCS Haryana Agricultural University, India

Ravinder Singh Dhillon, CCS Haryana Agricultural University, India

Sushil Kumari, CCS Haryana Agricultural University, India

Karan Singh Ahlawat, CCS Haryana Agricultural University, India

Environmental sustainability and multiple ecosystem functions in an agroecosystems may be enhanced by adopting agroforestry land use systems (AFS). In the present study, we focused on winter wheat variety (WH-1105) under six year old poplar (*Populus deltoides*) windbreak delimited by a row of deciduous poplar trees in East-West and North-South directions (E-W tree line divide farmlands into two aspects i.e. Northern and Southern and N-S tree line divide into Eastern and western aspect). While effects on crop produce were limited with the increasing distance from tree line, considerable yield reductions were found near tree line at a distance up to 3m. On an average, the maximum grain yield of wheat (3.45 t/ha) was recorded in north-south row direction of poplar windbreak. The variable influence of tree line directions on yield in different aspects might be attributed to micro-site enrichment caused by favourable environment due to shade and leaf litter addition. The soil properties observed at different distances (0-3 m, 3-6 m, 6-9 m, 9-12 m, 12-15 m and 15-18 m) from tree line of poplar planted in East-West and North- South directions. The soil pH and EC showed increasing trend from 0-3m to 15-18m in all the aspects of East-West and North-South planted poplar windbreak. However, the organic carbon showed decreasing trend from tree line to 15-18m and higher organic carbon was recorded in western aspect followed by southern aspect. The available N, P and K also showed decreasing trend from tree line to 15-18m of poplar windbreak AFS.

### Agroforestry and intensive rotational grazing to maximize carbon sequestration within a pastoral cattle production system

\*Frédérique Lavallée, Université du Québec en Abitibi-Témiscamingue, Canada

Annie DesRochers, Université du Québec en Abitibi-Témiscamingue, Canada

David Rivest, Université du Québec en Outaouais, Canada

Vincent Poirier, Université du Québec en Abitibi-Témiscamingue, Canada

The cattle industry sector emits significant amount of greenhouse gases (GHG). The project, in partnership with Ferme Lafontaine-Noël (Dupuy, Qc, Canada), aims at developing innovative practices to increase carbon (C) storage in soils and biomass to offset GHG emitted by the farm's activity. The development of agroforestry systems on permanent grasslands can rapidly increase C storage in soils and biomass. Pasture management intensification, where an area is grazed for a short period, followed by an appropriate rest period, can also increase soil C storage and stability. The implementation of agroforestry systems on intensively rotational managed pastures could be doubly beneficial in terms of C storage. The 20 ha experimental site was divided in two treatments replicated in four blocks Treatment 1 (business as usual scenario), consist of continuous grazing for 10 days. Treatment 2 is an agroforestry grazing systems where grazing is carried out in intensive rotation (daily moves) within paddocks bordered with hedgerows of planted trees. The hedgerows were subdivided in four tree mixtures and three corresponding monocultures that included hybrid poplar (*P. maximowiczii* × *P. balsamifera*), red maple (*Acer rubrum*) and white spruce (*Picea glauca*). Soils were sampled at depths 0-10, 10-20, 20-40 and 40-60 cm to determine the initial quantities of C stored in soil and root biomass (spring 2020). Tree growth measurement and a second soil and root sampling of grazed areas and hedgerows were performed at the end of the second growing season (fall 2021). Results regarding the short-term impact of the agroforestry grazing system on carbon storage will be

presented. This project represents an opportunity to test the feasibility of implementing an agroforestry system at a commercial scale while allowing the partners to establish a long-term experimental site devoted to evaluate how agroforestry grazing systems can help reduce GHG emissions and mitigate climate change.

Farmers' Representative in this session: Frédérique Lavallée, Canada

Room 302

## F1. Transitioning to a Viable Economy

Agroforestry based integrated farming system transforms lives of small-holder farmers in Gujarat, India

\*Yogesh Sawant, BAIF Institute for Sustainable Livelihoods and Development, India

Rajesh Kotkar, BAIF Institute for Sustainable Livelihoods and Development, India

The tribal (aboriginals) communities are among the socio-economically disadvantaged in certain regions of India. In south Gujarat they mainly depend on agriculture for their livelihoods. Agriculture is however predominantly rainfed, characterized by small land holding, depleting soil cover, eroding crop diversity and increasingly erratic weather. These factors have significantly increased vulnerability of the farmers resulting in distress seasonal migration. BAIF introduced an "agroforestry based integrated farming system" popularly known as "wadi" for ensuring sustainable livelihoods for the small-holder tribal farmers. The activities implemented include soil conservation, soil improvement, multitier cropping including fruit and forestry trees, vegetables, intercropping through legumes and water conservation measures. The objective of this study is to assess the impact of "wadi" on the lives and livelihoods of the needy families. The hypothesis assessed is that the integrated farming system has resulted in increased farm income, improved diversity and resilience as against the conventional farming system (baseline). The method adopted for this study involved selection of 877 respondent families through stratified random sampling from the 1632 project families. A household interview tool was administered to the 877 families based on key indicators after 11 years of project initiation. The observations were computed and analyzed. The results indicate the significant benefits of "wadi" system as under: Increased crop diversity from average 2 crops to 6 crops per farmer. 8% farmers cultivating more than 9 crops, Increase in trees outside forest (2,53,000 trees) on 338 Ha, Increase in farm income by >100%, In-situ conservation of indigenous varieties of rice, beans and tubers, Distress migration reduced significantly. The agroforestry based integrated farming system offers significant economic, nutritional, environmental benefits and resilience to small-holder farmers. The tree species, also additionally offer hedging during financial crisis. It has high potential for wider emulation.

The impact of the increased shea nut demand and prices on collectors: livelihoods in Burkina Faso and Ghana

\*Mariève Pouliot, University of Copenhagen, Denmark

Francois Questiaux, University of Copenhagen, Denmark

Nerea Turreira Garcia, University of Copenhagen, Denmark

Commodity and value chains have received increasing attention over the past decades. They have proved to be a fruitful way to understand global connections over time and space, connections between economies and different markets, as well as transport, infrastructure, and geopolitics. In this paper, we focus the attention on the very start of the value chain and on a specific agroforestry product: the shea nut and its collectors in West Africa. Shea nuts constitute an important source of income for millions of women in West Africa who have collected and used them for centuries. Following the huge growth observed in the Cocoa Butter Equivalent (CBE) market since year 2000, export values of shea nuts have increased more than ten-fold. Since the collection of shea nuts is often not regulated, the boom in demand and prices creates space for different techniques of appropriation and possible exclusion at collection sites. This paper studies the impact of the increase in shea nut demand and prices on collectors' income and livelihoods. Through an analysis of a unique survey data collected on a sample of 1000 shea nut collectors in Burkina Faso and Ghana, we characterize the collectors who benefit from the increased market demand and those who don't. The paper discusses the impact of global market forces on local economies and lives, and sheds light on issues of income and access inequality. Results can inform policy making and development interventions aimed at transitioning to a viable economy in the agroforestry sector.

### Costs, income and profit in bovine production units that carry out silvopastoral practices in Chiapas, Mexico

\*José Apolonio Venegas Venegas, Conacyt-Unach, Mexico

Deb Raj Aryal, CONACYT-UNACH, Mexico

Mariela Beatriz Reyes Sosa, CONACYT-UNACH, Mexico

René Pinto Ruiz, Universidad Autónoma de Chiapas, Mexico

Francisco Guevara Hernández, Universidad Autónoma de Chiapas, Mexico

José Antonio Jiménez-Trujillo, CATIE, Mexico

Bovine farming is one of the economic activities of great importance in Chiapas, Mexico due to the amount of labor it uses, and the products and by-products derived from it. There are few employment opportunities in rural areas and the bovine production units (BPU) counteract the problem by generating income for the local families. Many BPUs have established different silvopastoral systems such as living fences, protein forage banks, energy forage banks, and scattered trees on pasturelands, which allow them to have important economic and environmental benefits. The objective of this study is to calculate the net profit of the BPUs to know if they are being profitable or not with silvopastoral practices. 30 BPUs were evaluated in the municipalities of Villaflores, Jiquipilas, Arriaga and Tonalá in Chiapas. For each BPU, an analysis of operating costs was carried out consisting of variable costs (cost of food, sanitary management, and labor), and fixed costs formed by the depreciation of equipment and tools. In addition, an income analysis of the products of the economic importance of each production unit was carried out, consisting of the sale of milk, meat, and cheese. Furthermore, the net profit and Benefit-Cost Ratios were calculated. The dual-purpose system (milk and meat) predominates with 67% and 33% single-purpose. 73% of BPUs obtained profits ranging from USD \$9.41 to \$18,341 per year, while 27% were with losses. On the other hand, the average cost-benefit ratio obtained by the BPUs that resulted in profits is 2.3, that is, for each USD invested they recover the investment and obtain \$1.3 of profit. We conclude that silvopastoral practices improve the profits of bovine producers in Chiapas, Mexico. Further economic analyses regarding supporting, regulating, and cultural ecosystem services of the silvopastoral systems are needed.

## Renovation and rehabilitation programs in Cocoa Agroforestry Systems: A financial optimization approach

\*Felipe Peguero, CATIE, Costa Rica

Eduardo Somarriba, CATIE, Costa Rica

Rolando Cerda, CATIE, Costa Rica

Luis Orozco, CATIE, Costa Rica

Cocoa-based agroforestry systems are assets whose productivity declines with age, affecting the livelihood of millions of farmers worldwide, contributing to deforestation, carbon emission, and biodiversity loss. The optimal time for Renovation and Rehabilitation (R&R) has always eluded agronomists and producers. Thus, in this paper we focus on two pressing questions: When to start replacing the old orchard (i.e., at what age)? and What fraction of the old grove to renovate annually? Under this motivation and following Perrin (1972)'s methodology, we derived a theoretical framework. It indicates that the optimal renovation time for a cocoa grove is determined by the sum of marginal cash flows and the opportunity cost of not establishing the new orchard. The marginal cash flows are defined as the potential cash flows obtained from holding the grove one more year. Similarly, the opportunity cost is defined as the potential return gained in the renovation period by money equivalent to the timber harvested, the challenger NPV, and the land value appreciation. A similar conclusion is obtained for a phase-out renovation. The results provide a simple way to analyze the optimal renovation period under various scenarios (i.e., fertilization, pruning, subsidies, varieties, etc). Thus, simple tools were derived for R&R's extension programs in for Latin America. Following Mahrizal et al. (2012 & 2014), we tested the theoretical framework with actual cocoa and coffee agroforestry systems data. Results from the theoretical model were equals to the numerical optimization. The model was applied to a cocoa agroforestry system in Costa Rica, yielding an optimal R&R in year 20. The model was also applied to a coffee agroforestry system in the Dominican Republic, which indicated that phase-out rehabilitation should start at year 10.

## Private and societal values of agroforestry systems in southern Quebec: how to enhance voluntary adoption?

\*Caroline Simard, Université du Québec en Outaouais, Canada

Jérôme Dupras, Université du Québec en Outaouais, Canada

Sylvia Wood, Habitat, Canada

Agricultural practices in southern Quebec have intensified over the past decades with impacts for biodiversity and water quality, especially in the Lake Champlain basin. The region has experienced recurring algal blooms over the last 20 years. Riparian buffer strips have been identified as one possible agro-environmental solution. Current public and private programs to encourage the uptake of agro-environmental practices to control nutrient pollution in Quebec have met with limited success to date. Socio-economic factors and the discrepancy between short-term interests of farmers and long-term interests of society have been major drivers slowing their adoption. Using Lake Champlain watershed in southern Quebec (Canada) as case study, the objectives of this study were: 1) to examine the economic value of marketable products and non-market ecosystem services yielded by three scenarios of riparian forest buffer management over the next 50 years using a cost-benefit analysis; and 2) to assess the effectiveness of the new agri-environmental policy Prime-Vert (2018) implemented in Quebec to enhance voluntary adoption using discounted cash flows analysis. Our economic model uses data set from WBVECAN simulation tool and adds new economic indicators to assess risk and option values for farmers. The scenarios were designed to include contrasting socio-economic goals (minimal area, maximal biomass production, ecological and aesthetic value). Scenarios differs in terms of width, species composition and ecological complexity of the planted

buffers. Our results show that, under current policy, none of the scenarios achieve rentability from a farmer's point of view. However, when we consider the societal value of non-market ecosystem services such as water quality improvement and habitat provision for species, all scenarios become socially profitable. These results provide a rationale for market-based instrument such as payments for ecosystem services. We will also discuss how this approach can inform the public regulator on the timing of payments and how to consider risk and option values for farmers to enhance the voluntary adoption of agri-environmental practices.

Farmers' Representative in this session: Erminda Pacheco & Eulogia Isabel Cordoba, Colombie

Room 301B

## H2. Transitioning to a Viable Development

### Agroforestry in Madagascar: Past, Present, and Future

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Madagascar is one of the hottest biodiversity hotspots in the planet, regions with an outstanding biodiversity wealth coupled with severe threats to its habitat, in this case forests. In parallel, Madagascar is one of the least developed countries in the world, with a majority of the population relying on subsistence agriculture as main economic activity, which in many cases encroaches on forested areas. For decades, agroforestry has been considered as a potential solution for the conservation and development challenges Madagascar faces, although no systematic knowledge is available on the history, successes and failures of agroforestry in the country. In this paper, we synthesize knowledge on the history of agroforestry in Madagascar, and on the co-benefits and trade-offs agroforestry has encountered in the recent past and to present time in. We then apply this knowledge to draw scenarios to highlight the role that agroforestry may play in conservation and development interventions, including restoration activities. We adopt a systematic review of scientific and grey literature paired with an online survey with program representatives of NGOs promoting agroforestry currently, to gather their views on the future of these agricultural systems in the country, and validate the review findings. This study provides an up-to-date knowledge of the agroforestry sector in Madagascar, including scenarios of areas with potential to implement agroforestry projects in the future. By making this knowledge available, our research can hold significant potential for informing development and conservation policy and practice on Madagascar's forest frontier.



### Climate information services in the agrosylvopastoral sector of the North Region of Cameroon: a review of institutional arrangement and its implication on rural livelihoods resilience needs

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Denis Sonwa, CIFOR-ICRAF, Cameroon

Ann Degrande, CIFOR-ICRAF, Cameroon

Adamu Idris Tanko, Bayero University Kano, Nigeria

The North Region of Cameroon is made of different farming systems where trees play an important role. These rain-fed farming systems are now threatened by climate change and variability. Besides agronomic solutions commonly proposed to face this phenomenon, agroforestry as well as the application of climate information services is receiving increasing political and scientific interest as a climate-smart approach for climate change mitigation and adaptation in dryland. The Government of Cameroon has expressed interest in climate information services by setting up a national strategy for the offer of climate information services which has attracted the attention of different actors in the agrosylvopastoral sector of the North Region. The paper explores the institutional setup of climate information in the North Region of Cameroon and discusses its implication on rural livelihoods' resilience needs. The paper draws on a literature review on climate change, climate change adaptation, agrosylvopastoral system, rural people resilience needs, actors (government, non-governmental and parapublic services, private sector, and producer organizations) involved in the production and dissemination of climate information in the North Region of Cameroon. Results show that while actors involved in climate information services are numerous, they are financially and technically constrained. Besides, the absence of a formal collaborative framework defining the roles of each actor leads to duplication of actions and constrains the co-production of information. The aftermath is that climate information produced is not sufficiently actionable, timely, and contextualized to meet rural people's needs and improve their decision-making on climate change adaptation. The paper concludes that institutional barriers must be reduced to accelerate the deployment of climate information services in the North Region of Cameroon.

### Agroforestry data visualisation and engagement processes that can enhance integration for policy related decision making in Kenya

**\*Mieke Bourne**, CIFOR-ICRAF, Kenya

Christine Magaju, CIFOR-ICRAF, Kenya

Constance Neely, CIFOR-ICRAF / SHARED, United States

Nathanial Peterson, Busara Center for Behavioural Economics, Kenya

Tor-G Vågen, CIFOR-ICRAF, Kenya

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Leigh Winowiecki, CIFOR-ICRAF, Kenya

Sabrina Chesterman, CIFOR-ICRAF, South Africa

Research evidence is continuously generated, but often not used adequately to guide policy decisions. To understand more about this understudied topic, we conducted a two-part behavioural study linked to the development of the Agroforestry Strategy for Kenya. In the first part of the study, a survey of 174 relevant stakeholders sought to understand data visualisation preferences using pairwise comparisons. Analytic Hierarchy Process was used to analyse the results and determine the preferred visualisations by different groups. The second part of the study involved comparing two virtual workshop types, a peer-led workshop and a facilitated workshop designed using the Stakeholder Approach to Risk-informed and Evidence-based Decision-making (SHARED). Participants were randomly assigned to the two workshop types, both of which were designed to contribute agroforestry supportive strategies. In the peer-led workshop a data pack and instructions



for breakout groups was provided, and the group work observed. For the facilitated workshop, a data wall was presented, and the breakout groups were facilitated. A post-workshop survey filled by 63 participants, facilitator reports, coded transcriptions of group discussions and strategy content were analysed. Results from the visualisation preference survey indicate that while most respondents preferred tables and bar charts over ridge and box plots, the preferences were not consistent, suggesting uncertainty in the visualisation preferences. Triangulation across different data sources associated with the workshops indicate the facilitated workshop provided greater inclusion of and contributions by participants, however, many participants in peer-led groups also felt included. Information from the data packs was often referred to in the peer-led workshop but in the facilitated workshop, strategies integrated the presented data sources more frequently. Results from this study provide valuable insights into how data presentation and facilitation can support evidence-based decision making. Further insights are needed in this field to support greater application of research outputs for policy.

### Because it makes sense for us - Examining Farmer Perspectives on the Potential to Scale Up Agroforestry in the New York Dairy Sector

\*Kristen Jovanelly, Dartmouth College, United States

\*Lily Colburn, Yale University, United States

\*Luca Guadagno, Yale University, United States

Large-scale tree planting projects have been prominent in many natural climate solutions initiatives and have garnered international interest and financial support from the public and private sectors. Policymakers and scientists have proposed that tree planting projects should be implemented on marginal farmland, or by establishing agroforestry in new or existing agricultural systems. Although the carbon sequestration benefits of expanding agroforestry are attractive at the policy level, agroforestry also provides a suite of on the ground outcomes for farmers. A robust understanding of the varied perspectives, needs, and motivations of farmers and technical advisors on the ground is critical in assessing the implications, feasibility, and durability of tree-planting programs on working agriculture landscapes. In the absence of this research, policy that aims to amplify the short- and long-term success of agroforestry on diverse agricultural landscapes will not be realized. In this presentation, we will share our research on the feasibility of establishing agroforestry in new or existing agricultural systems in the New York dairy sector. We will explore key findings from stakeholder engagement with thirty extension agents and over twenty dairy farmers with diverse land management and production strategies across New York. We will review current trends on how farmers engage in agroforestry and tree management, perceived opportunities and motivations for adopting agroforestry, and anticipated challenges. In addition, we will share our results on enabling factors on and off farms necessary to catalyze farmer adoption and support the long-term success of agroforestry in the New York dairy sector, as well as across the Northeast. This presentation will elevate the perspectives of potential agroforestry adopters, their knowledge sharing networks, and provide insight for policymakers on how tree planting initiatives can best reflect the values and needs of the land managers responsible for the sustained success of trees in agricultural landscapes.

### Riverbank carbon: Agroforestry is the way to unite carbon emitters to farmers while protecting watercourses

\*Simon Côté, Arbre-Évolution Coop de solidarité, Canada

We are Arbre-Évolution Solidarity Coop, a group dedicated to Earth. Carbone riverain™ (Riverbank carbon) is an ambitious program which offers a way to compensate for GHG emissions. The program was launched in October 2021. Its objective is

simple: to improve our rivers' water quality. And this goal can be achieved namely by widening farm land buffer strips along watercourses. Carbone riverain™ relies on a financial incentive system encouraging farmers to take part in an important movement for the conservation of riverbanks. Development projects includes the implantation of canopy trees, edible shrubs and seeding to ensure good pollinization. Through a monitoring protocol and proven methodology, Carbone Riverain™ promote, in a new way, the concepts of air quality, water protection and ecological integrity by using a single carbon credit formula. This scientific work notably produced specific data on the potential of trees and shrubs to sequester atmospheric carbon on farm lands. Carbone Riverain™ is also highlighting the potential of sequestering carbon in the soil and its other applications. At the end of a dedicated research focusing on the soil potential in 2019, we were able to determine the annual sequestration rate of the evolving soil and organic components present in the riverbank plantations conducted by the Program. In essence, following the monitoring of all research efforts conducted in the past three years, we found that projects implemented by the program can offset more than 2,500 tons of CO<sub>2</sub> per hectare over 40 years of growth. Lastly, an ongoing research protocol will be established to generate data, which will allow us to evaluate the sequestration rate of all projects, to spread light over the ecoservices of the nature and to make an important contribution to science.

Farmer's video: agroforestry in Cameroon

Room 301A

## K2. Which Agroforestry for Annual Crops?

A low soil-disturbance agroforestry system in Taiwan - cultivation of a medicinal orchid, *Anoectochilus formosanus*, under forest

\*Fen-Hui Chen, Taiwan Forestry Research Institute, Taiwan (Republic of China)

Shu-Hwa Chang, Taiwan Forestry Research Institute, Taiwan (Republic of China)

In Taiwan, the management of any agricultural activity was restricted by laws and regulations on forest land. However, illegal land use or over-utilization of hillsides has been difficult to eliminate. In order to share the forest ecosystem service values and boost the green economy, Taiwan Forestry Bureau officially accept applications for forest by-products under the premise of not destroying the forest environment since 2019. Taiwan Jewel's orchid, *Anoectochilus formosanus* Hayata is an endemic orchid of Taiwan growing in the humus-rich soil under broad leaf and bamboo forests at elevations of 500–1,600 m. This important medicinal herb has been used for hypertension, diabetes, heart, lung and liver diseases. The wild populations are under the threat due to overharvesting. Several reports indicated that its active ingredients are higher in forest farming system than in greenhouse or flask cultivation systems. However, soil disturbance may be an issue if cultivated on forest-floor directly. *A. formosanus* plantlets are mass propagated by micropropagation. When plantlets are 4-5 cm (about 5 months in vitro culture), they are transplanted to plastic mesh basket containers, covered with net to avoid pest problems. We suggest to use commercialized peat soil mixing with perlite or vermiculite (2:1) to reduce weeds. The whole set then is placed on forest-floor where the environment is suitable. Only 2% gap of forest land is allowable to use. The whole plants are harvested after 8-10 months growth, especially before blooming. The estimated market value of a 0.02 ha planting area in 1-ha forest can reach USD13,200. In our system, soil disturbance during cultivation and harvest are

minimized. The development of environmental-friendly management model for forest farming is about sharing the multi-service values of the forest ecosystem, with the core indicators of not destroying the forest, sustainable management, and harmony between men and nature.

### Transformation of orchards to agroforestry systems for maximizing production, income and microenvironment

\*Giashuddin Miah, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh

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Shrinking land, decreasing soil health, deforestation, climate hazards are some of the major challenges in improving and sustaining agricultural production in South Asian countries including Bangladesh. Nowadays, various fruit orchards are being established in agricultural landscapes, which are not being examined scientifically. Moreover, owing to augmenting the demand of vegetables and fruits, the cultivation of vegetables in orchards are being opened as a new prospective approach for the farmers especially small-holders. In the present study, three orchards namely, guava (*Psidium guajava*), jujube (*Ziziphus jujube*) and malta (*Citrus sinensis*) were transformed to agroforestry systems through inclusion of seasonal vegetables (okra, Indian spinach, kangkong, broccoli and bottle gourd) and spices (ginger and turmeric) from February 2018 to April 2020 to identify the suitable vegetables for fruit tree-based agroforestry systems in terms of productivity, profitability and microenvironment. Randomized complete block design with three replications was followed, where distances from tree bases were considered as treatments for each crop. Vegetable yields were increased with the increase of distances from the tree bases and the average yield reduction was 11%. In agroforestry system, only 18% of land was used for spices, which ultimately boosted total production and maximized land utilization. Inputs applied for the associated crops were enjoyed by the trees that helped increasing fruit yields by 21%. Light was not a limiting factor in agroforestry at the early stages of fruit trees, while at the later stages (third year), it was interrupted slightly owing to increased tree canopy. Soil temperature and moisture were found favorable in agroforestry systems than in sole annual cropping. The utmost BCR and LER obtained in agroforestry systems clearly indicated the maximum seasonal returns. In conclusion, fruit tree-based agroforestry system can be a promising production system in providing higher production, economic benefits, boosting nutritional security and favorable production environment.

### Effects of agroforestry tree species on weed species distribution at the long-term agroforestry trials site, Juja, Kenya

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Shem Kuyah, Jomo Kenyatta University of Agriculture and Technology, Kenya

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Human population are tending to grow beyond the carrying capacity of local environment and their resources, hence the need to innovate ways of increasing food production. The Agroforestry Long-Term Trials (LTT) at Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya was started in the year 2011 by enhancing beneficial tree-crop interaction by exploring best suit tree species combination and management practices to optimize crop productivity. The main objective was to study the weed diversity and the relationship of the weeds with the individual agroforestry tree species within the

trial plots. The site is located within the University farm at Latitude 10° 05' S, Longitude 37° 00' E, and at an altitude of 1528 m above sea level and is classified as agro-ecological zone IV which correspond to a semi-arid climate. The trials involved three agroforestry tree species (*Cordia africana*; *Faidherbia albida*; Mixed species) and a control (with no tree species) all replicated four times in a randomized complete block design (RCBD). We conducted the study on weed diversity within the system to understand how different treatments of agroforestry tree species affect weed distribution. The methodology used in collecting the data in this study involved direct observations, line transects and patterned searches. The results showed that 107 taxa from 21 families were recorded with *Dyschoriste nagchana* (Nees) Bennet and *Sporobolus pyramidalis* P. Beauv. recording the highest species richness across the trials. Similarly, the family Poaceae recorded the highest number of taxa within the trial plots. *Cordia africana* tree species recorded the highest number of weed taxa while *Faidherbia albida* recorded the lowest. Weeds cause heavy crop yield losses, hence, identifying the tree species causing reduced weed density will pay dividends in that it will serve two purposes: i) reduce the cost of weed control and ii) increase in crop yields.

### Economic performance of floriculture crop as influenced by organic manures and tree spacing under *Grewia optiva*, Drummond. based agroforestry system

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Background: Incorporation of floriculture crop in agroforestry may prove a profitable venture but having meager information. The present investigation was conducted at Dr YS Parmar University of Horticulture and forestry, Nauni, Solan (H.P.) during 2012-2014. Objectives: The investigation was carried out to study the bio-economic feasibility of floriculture crop under fodder based agroforestry system. Methods: Experiment consists of two structural and functional components viz., *Grewia optiva* Drummond. trees as woody perennial and floriculture crops viz., *Dianthus barbatus* L. and *Godetia grandiflora* L. (winter annuals), *Callistephus chinensis* (L.) Ness. and *Gomphrena globosa* (summer annuals) as intercrops in agri-silviculture system. The impact of different doses of FYM, Vermicompost, Municipal solid waste and PGPR on performance of floriculture crops, with and without tree component was studied. Treatments consist of four tree spacing i.e. 8m×1m, 8m×2m, 8m×3m and control, and eight organic manure combinations replicated three times under split plot design. Results: Results reveals that growing of floriculture crops under *Grewia optiva* based agroforestry system is quite profitable than growing sole floriculture crop. Agroforestry system comprising of *Grewia optiva*+*Godetia grandiflora*+*Gomphrena globosa* shows less benefit:cost ratio i.e. 1.66-1.71 for the agroforestry system whereas it was 1.55 for the sole crop during year 2012-13 and during year 2013-14, 1.89-1.92 for agroforestry system and 1.75 in open condition, as compared to the agroforestry system comprises of *Grewia optiva*+ *Callistephus chinensis*+*Dianthus barbatus* where benefit:cost ratio was 3.63-3.78 for system and 3.53 in open condition during 2012-13 and for the year 2013-14, 3.04-3.10 under system and a little higher (3.11) in open condition. Conclusion: *Dianthus barbatus* was found to be the better flower crop under agroforestry system. Vermicompost @2.00kg/ plot+PGPR and FYM @5.00 kg/plot+PGPR were found best doses of organic manures for both winter and summer annuals grown under agroforestry system and in open condition.

Farmers' Representative in this session: Mark Kebo Akparibo, Ghana

Room 203

## L2. Which Agroforestry for Commercial Perennial Crops and Trees?

How intensification-sustainability strategies influence the regulation of pests and diseases in coffee agroforestry systems

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Fernando Casanoves, CATIE, Costa Rica

Jeremy Hagggar, University of Greenwich, United Kingdom

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Clémentine Allinne, CIRAD, France

Pests and diseases (P&E) cause coffee losses that threaten the well-being of millions of rural families. Coffee farmers manage their agroforestry systems with strategies that combine levels of agronomic intensification and diversity of vegetation. Different strategies lead to particular injury profiles (set of P&E incidences) which in turn cause certain yield losses. In this research we evaluated 180 coffee plantations in a wide range of management intensities and agroforestry compositions, and in contrasting agroecological conditions in Costa Rica and Guatemala, with the objectives of: analyzing the associations of injury profiles and losses under distinct strategies, and identifying possible combinations of intensification and sustainability practices that regulate the impacts of P&E. We measured P&E incidences, yield loss indicators (dead branches and branches with die-back), diversity and shade cover in the field, and through interviews we collected information on management and costs. Our results show that the injury profiles that cause the major coffee losses have the highest incidence of rust (>60%) and also highlight other diseases such as brown eye spot and anthracnose; furthermore, these profiles are more associated with lowlands and with strategies of low investment in fertilization and P&E control (low intensification), and low shade cover. Among the practices that most contribute to reducing losses are the use of disease resistant varieties, fertilizations that especially provide Phosphorus and Potassium, and shade cover levels of 40-60%, which can yield >30q/ha of green coffee. Overall, our findings suggest that it is possible to apply strategies that combine intensification with sustainability (reflected by diversity and shade cover), which result in an expression of manageable injury profiles, with reduced losses and good yields. This is an important message and support for technicians and farmers to promote and/or adjust this type of strategy to Central American coffee plantations.

Early signs of a secondary outbreak of *Mycena citricolor* in an organic coffee farm in southern Mexico

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Kevin Li, University of Michigan, United States

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Coffee leaf rust caused by *Hemileia vastatrix* and American leaf spot disease by *Mycena citricolor* are important coffee fungal diseases that can cause severe yield losses. While coffee leaf rust received much attention from the recent regional outbreak in Latin America, here we report on an associated pattern of American leaf spot with the presence of coffee leaf rust in an organic coffee agroforestry farm in southern Mexico. Based on seven months of sampling for disease incidence and severity

of both coffee leaf rust and American leaf spot, we show that the incidences of the two diseases are not independent. Chi-square analyses of contingency tables of coffee leaf rust and American leaf spot presences show significantly fewer coffee plants infected with both diseases and more plants infected with only one of the diseases than expected at random. The resulting patterns of infection are consistent with the hypothesis that there may be trade-offs in controlling these pathogens, where the resistant varieties to the coffee leaf rust that were planted in response to the recent outbreak may be more susceptible to American leaf spot. These results suggest that management strategies for the control of the coffee rust in coffee agroforestry systems should not rely on planting homogenous resistant varieties and must take into consideration the community of pathogens that infect coffee.

### Influences of climate variability on cocoa health and productivity in agroforestry systems in Ghana

\*Bismark Kwesi Asitoakor, University of Ghana, Ghana

Richard Asare, International Institute of Tropical Agriculture (IITA), Ghana

Anders Ræbild, University of Copenhagen, Denmark

Hans Peter Ravn, University of Copenhagen, Denmark

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Kwadwo Owusu, University of Ghana, Ghana

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Philippe Vaast, CIRAD, France

The susceptibility of cocoa to harsh climatic conditions is visible in cocoa growing areas in Ghana, and climate distribution models show reduced cocoa suitability with climate change. We hypothesized that decreased rainfall with corresponding elevated temperatures would negatively affect cocoa health and productivity. We assessed cocoa health and productivity for 4 years in 23 cocoa farms along a rainfall and temperature gradient from Ghana's southern, middle, and northern cocoa belts. Twenty cocoa trees per farm (in total 460) were observed and scored for their canopy condition, flower intensity, and damaged pods due to mirids, cocoa shield bugs, and black pod disease. Harvested pods and extracted dried cocoa beans were evaluated to ascertain yield/productivity. Insect pest damages to pods was on average  $2.3 \pm 0.8$ ,  $2.2 \pm 1.0$ , and  $3.0 \pm 0.7$  pods tree<sup>-1</sup> year<sup>-1</sup> in the south, middle and north, respectively. The healthiest and highest yielding trees were in the rainy south at  $0.99 \pm 0.02$ kg dry beans tree<sup>-1</sup> followed by the middle ( $0.84 \pm 0.02$ kg) and the north ( $0.60 \pm 0.01$ kg). However, black pod disease infection was highest in the south at  $1.1 \pm 1.1$  pods tree<sup>-1</sup> year<sup>-1</sup>, followed by the middle ( $0.7 \pm 0.8$ ), and the north ( $0.4 \pm 0.6$ ). We conclude that although cocoa performance, pests and disease are influenced by climatic conditions, farm management practices are key to the enhancement of productivity.

### Ecological regulation of the citrus foot rot disease caused by *Phytophthora* by optimizing structural characteristics of the cocoa-based agroforestry system

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\*Ndo Eunice Golda Danièle, IRAD, Cameroon

Bidzanga Nomo Lucien, IRAD, Cameroon

Tropical agroforest systems are currently recognized as an attractive means of reconciling productivity and ecosystem services without compromising the agrosystem. However, optimizing ecosystem services requires investigating the potential for restructuring existing agrosystems and supporting interactions within them. In this study, we evaluated the combined

effect of shading and spatial structure in cocoa-based agroforests (CBAS) on Phytophthora foot rot disease on citrus (PFRDC). A network of 33 experimental plots of 2500m<sup>2</sup> within CBAS was established in five citrus production sites in the humid forest zones of Cameroon. The experimental plots were mapped and the trees characterized. The citrus spatial structure trees were analyzed by Ripley's method, and the shading rate received by each citrus tree, calculated at the level of the citrus canopy, was quantified by the Shademotion 5 software. Subsequently, 225 citrus trees, divided into 9 treatments, were observed according to their shading situation (dense shade, light shade, or full sun); and their spatial structure (regular, aggregated, or random). PFRDC intensity was quantified on each citrus and measured on a scale of 1 to 5, where 1 represented a healthy citrus and 5 represented a citrus with the foot almost completely invaded by the lesion. Results showed that citrus planted under dense shade were significantly less attacked by PFRDC than those planted in full sun. Similarly, CBAS in which citrus had a regular spatial structure were significantly less attacked by PFRDC than plots in which citrus trees were clustered. Citrus trees planted in dense shade and with a regular spatial structure were significantly less attacked by PFRDC compared to those in full sun and with an aggregated spatial structure. These results show that appropriate management of shade and spatial structure in CBAS can significantly contribute to the control of PFRDC and thereby promote citrus production in complex agroforests.

### Diagnosis of service tree (*Sorbus domestica* L.) dieback in an experimental Mediterranean agroforestry system

\*Marilyne Laurans, CIRAD, France

Yves Caraglio, CIRAD, France

Jean-Luc Maeght, IRD, France

Agroforestry is one of the keys to the agroecological transition. In 2008, it represented 172 500 ha of French farmland. In Hérault, at the Restinclières estate, an agroforestry research platform has been implemented in 1995 with two main tree species: hybrid walnut, *Juglans nigra* x *Juglans regia*, and service tree, *Sorbus domestica* L. The service tree is a multifunctional and overlooked species of growing interest for agroforestry, forestry and urban use. Although considered drought resistant, a decline of this species has been observed on several plots within the site. The objective of this study is to identify the factors causing service tree dieback by using intra- and inter-plot variability in tree performance and retrospective analysis of growth. We assessed and quantified tree decline through architectural diagnosis. We then tested the role of water stress by focusing measurements on soil water status and root characteristics while examining several aboveground structural and functional traits. The first results highlight major water stresses over several years with differentiated impacts on the above and belowground architecture and development of trees. They show the importance of providing insights on the resilience of the service tree, in order to guide the choices of its implantation in agroforestry systems but also in forestry and urban environments.

### Farmer's video: agroforestry in Cameroon



Room 303A

## O2. Agroforestry - an Essential Pillar of Agroecology

Agroecological trajectories of farms belonging to the territorial agricultural model in Québec, Canada

\*Marc-Antoine Fortin, Université Laval, Canada

Alain Olivier, Université Laval, Canada

As agroecology and agroforestry gain more and more attention, a proliferation of alternatives to conventional farming, that some actors associate to a territorial agricultural model, is observed. While these approaches share, as a breeding ground, social and ecological concerns, the extent to which they overlap remains unclear. This research aims to shed light upon the social and agronomical practices used in farms that belong to the territorial agricultural model in the province of Québec, including farms practicing agroforestry, and the extent to which they adhere to agroecological principles. The analysis was based on a survey that was elaborated to score 38 farms on a 100-points scale used to position them on the spectrum of the agroecological transition. The survey was distributed through three networks of farms: two farmer cooperatives and one association for the promotion of regional food products. The results suggest that, based on the level of integration of the agroecological principles in their practices, three groups of farms stand out: limited integration (24%), integration of only the most common practices (55%) and comprehensive integration (21%). While it remains difficult to determine if the social and technical itineraries of these farms converge towards a holistic integration of agroecology key principles, the profile of many farmers showed the presence of precursor elements indicating the emergence of an agroecological movement in Québec. Through their agronomic interventions and their social engagement, these farmers demonstrate that they are inhabited by a strong will to contribute to redesign agroecosystems and foster a sustainable food system. The results of this research could serve as a source of inspiration to identify avenues for adoption of agroforestry, pointed out by farmers, in many instances, as a reference in terms of agroecological practices.

Band approach: tool for scaling the Farmer Managed Natural Regeneration from the plot to the communal land in Senegal

\*Gora Mbaye, Enda Pronat, Senegal

Farmer Managed Natural Regeneration (FMNR) is an endogenous strategy used by some Sahelian communities to regreen agrosystems and improve soil fertility. It consists of protecting and managing the natural regrowth produced by the stumps of trees and shrubs in the fields. However, its adoption from plot to communal land scale remains limited. In these agroecological intensification projects, Enda-Pronat carries out activities to promote in large-scale this agroecological practice in the groundnut basin. The aim of this study is to share the process of scaling up FMNR from field to communal land. In 2015, FMNR was practiced at the plot spatially, which created many constraints. To cope with this situation, FMNR bands (network of contiguous plots) were installed. For their implementation, Enda-Pronat carried out a census of the producers who had plots grouped together on the same site. These producers identified were subsequently trained in FMNR techniques. To strengthen natural regeneration in low-density bands, agroecological actions were integrated like practice mulching so that to trap seeds against high winds, pen the cattle in field crops before the rainy season in order to improve seed germination rate and spread organic manure. An inventory is carried out every three years to monitor the dynamics of regeneration in FMNR belt. In terms of result, after five years of FMNR practice, the organization of FMNR in belt has made it possible to secure it from free-ranging animals. Thus, the surfaces in FMNR have gone from 25 ha in 2015 to 658 ha in 2020. In addition, the flora richness in FMNR band is 49 species, against 42 in the fields without FMNR. In addition, in FMNR

bands, the density was 8 individual/ha in 2015 against 39 individual/ha in 2020. This information may help decision-making in the Sahel regreening programs.

### Developing site suitability model for Ramps - A forest farming approach

Pabitra Aryal, Virginia Polytechnic Institute and State University (Virginia Tech), United States

\*John Munsell, Virginia Polytechnic Institute and State University, United States

John Fike, Virginia Polytechnic Institute and State University, United States

The ramp (*Allium tricoccum*), a native spring ephemeral also known as the wild leek, is a cultural keystone species in Appalachia, a mountainous physiographic region encompassing 205,000 square miles in the eastern United States. People in Appalachia have long harvested ramps in the wild. However, growing demand for the plant in and outside of the region have increased harvesting, which has resulted in threats to native populations. To conserve ramps and meet increasing demand, agroforestry cultivation techniques and technical support for sustained-yield forest farming practices are needed. Forest farming can create greater product value, supply global markets, and reduce pressure on natural populations. One important step for increasing forest farming of ramps is to help producers identify suitable sites for ramps cultivation. Our project seeks to model site suitability for ramps and develop a freely-available online site assessment tool for agroforestry producers. Using a Geospatial Information System at 10m<sup>2</sup> resolution, we created seven habitat suitability maps for seven counties in four states in the Appalachian region. We used weighted linear combinations of 10 different habitat criteria for ramps growth. Comparison of site suitability maps with ramp patch locations indicated that most ramp patches fall within the model's estimate of moderate to high suitability ranges. We aim to use this information to revise ramp site assessments within PlantShoe, an existing web / Android tool developed by the Center for Geospatial Information Technology at Virginia Tech. Our research benefits ramp producers and the forest farming community more generally, with increases in productivity and agroforestry systems establishment via rapid and remote habitat assessments. Such modeling procedures and site analysis systems are useful for other woodland botanicals the world over that need rapid, science-based site suitability analyses at large scales.

### Poverty threatens agroforestry systems in Kaliro, Uganda

\*Cory Whitney, University of Bonn, Germany

John Tabuti, Makerere University, Uganda

Forests and agroforestry areas of Kaliro Uganda are on the decline. Local experts have in-depth knowledge about trends and hold important information that can lead to the identification of potential solutions. We held focus group discussions with local officials, community members and farmers to learn about the drivers of deforestation and potential solutions. These groups shared their impressions with us, that the loss of trees impacted local lives and livelihoods. Tree loss has led to locally declining rainfall, soil erosion, loss of soil fertility, declining crop harvests and subsequent food shortages. The loss of tree cover has also meant strong winds, more droughts and lower air quality. Without trees, fruits are in smaller quantities and varieties and firewood is harder to come by. Tree loss is driven by poverty and the need for charcoal and timber. Local people cut trees for firewood collection and expanding agricultural land (especially sugarcane). Building and road expansion and construction also drive tree loss. Country-wide peace and stability, together with good communication with traders and markets and improved road networks, increase the draw for tree products. Traders come from far and wide to collect tree products for outside markets. People in Kaliro appreciate the value of trees and are willing to plant, but do not have land to plant the trees on. They suggest interventions that ensure land rights, establish tree nurseries and supply accessible

seedlings together with monitoring and advice. Supplying seedlings at the start of the rainy season will ensure that trees can be planted when there is plenty of rain and they can flourish. Continuous community sensitization and exemplary tree planting on parish and church land. Likewise, deterrents to cutting young trees and fruit trees could be effective, i.e. a cut and plant policy (cut 1 and plant 2).

### Agroforestry Education in Southeast Asia: Prospects and Challenges

\*Leila Landicho, Institute of Agroforestry, University of the Philippines Los Banos, Philippines

Wilfredo Carandang, Institute of Renewable Natural Resources, University of the Philippines Los Banos, Philippines

Rowena Esperanza Cabahug, Institute of Agroforestry, University of the Philippines Los Banos, Philippines

Jose Nestor Garcia, Institute of Agroforestry, University of the Philippines Los Banos, Philippines

Delia Catacutan, World Agroforestry (ICRAF), Philippines

Nhyria Rogel, Southeast Asia Regional Center for Research and Graduate Study in Agriculture, Philippines

Agroforestry is increasingly recognized as among the most effective strategies in building resilience of ecosystems and communities. An assessment in 2018 revealed that 60 of 147 countries explicitly proposed agroforestry as a solution in their nationally-determined contributions. In spite of this, it has been recognized that a lack of professionally trained agroforesters, impedes wider adoption at local levels. The ASEAN Guidelines for Agroforestry Development identified 'research and continuous learning' as one of the key implementation considerations. This includes the 'development of agroforestry curricula to ensure that agroforestry is taught in institutes of higher education. The state of agroforestry education in Southeast Asia was assessed in 2021 based on reports from four countries in the region, namely: Indonesia, Malaysia, Philippines and Vietnam. The assessment revealed that agroforestry's potential in improving livelihoods and ecological stability is being recognized in tertiary education in the region, as indicated by the existence of formal agroforestry education programs in the four countries. There are now 32 state colleges and universities in the Philippines offering different types of agroforestry education programs; 18 in Indonesia and two in Malaysia. However, there are challenges confronting the offering of agroforestry education in Southeast Asia. These include the downward enrolment trend, outdated and less attractive agroforestry curricula, limited public awareness about agroforestry, limited learning resources has been a downward enrolment trend in agroforestry courses and limited employment opportunities for the graduates. Consider the prospects of agroforestry being a key solution to addressing the world economic and ecological challenges, there is a need to review and revise agroforestry curricula, involving multistakeholders; improve the learning resources; intensify student recruitment programs and innovative career orientation programs; strengthen the national and regional collaboration in agroforestry education, research and development; ensure job placement for agroforestry graduates.

Farmers' Representative in this session: Marc-Antoine Fortin, Canada

Room 204A

## Side Event - Book Launch: Tree Commodities and Resilient Green economies in Africa (ICRAF)

**Book Summary:** The book *Tree Commodities and Resilient Green economies in Africa* is about tree crop commodities in Africa and it sought to examine how best Tree commodities can contribute to achieving sustainable development goals in Africa. It is premised on tree commodities (coffee, cocoa, coffee, cashew, oil palm, rubber etc.), representing some of the continent's fastest-growing land uses. These commodities support the livelihoods of millions of people and constitute an essential part of African economies. At least five countries in Africa are single tree commodity-dependent economies. Seven more economies can be considered tree commodity-dependent when more than one tree commodity is considered. Nevertheless, farmers remain poor because prices remain low, and most crops are exported as raw materials or with little processing. Hence, countries capture very little of the total value of the commodity value chains. For example, Africa produces 75% of the world's cocoa but captures less than 10% of the total market value of the commodity. Fluctuating prices pose serious balance of payment challenges for economies as well.

There is also evidence that these commodity systems have flourished at the expense of forests and come with several other externalities- social (e.g., land conflicts, land grabbing), climate (e.g., greenhouse gas emissions) and environmental (e.g., biodiversity loss- including soil micro-organisms; human health impacts from pesticides use). Climate change poses a significant existential threat to some of the commodities. As global demand for these commodities continues to soar, expansion is also being limited by land scarcity. Therefore, tree commodity systems would need massive innovations to respond to today's climate change and social, economic, environmental and land scarcity challenges. This book aims at furthering the understanding of innovative options for enabling continued economic, livelihood and ecosystem services benefits for people through climate-smart and sustainable tree commodity systems.

The book focused on five key tree commodities grown in Africa: cocoa, coffee, oil palm, rubber and cashew nuts. It is structured in seven parts. Part I explains the motivations of the book, and Part II explores commodity-based case studies from the systems innovation's perspective. Parts III, IV and V examine economic, environmental and governance innovation options, respectively. In part VI, the book presents lessons from across Asia and Latin America that could benefit thinking green tree commodities and Part VII teases emerging lessons from the book and envisages possible ways forward.

**Target Audience:** We target a non-specialist audience of those in evaluating and designing existing or new public-sector responses, civil society involvement and private sector initiatives. The chapters aim

to provide a basic understanding of the various issues and refer to recent or foundational literature that can be consulted for further depth

*Minang, P. A., Duguma, L. A., van Noordwijk, M. (Eds) (2021) Tree Commodities and Resilient Green Economies in Africa. Nairobi, Kenya: World Agroforestry/ICRAF*

Chair: Peter Minang - Director for Africa CIFOR - ICRAF

Co-chair: Meine van Noordwijk- Principal Scientist CIFOR -ICRAF

*Lunch break: 12:00 to 1:30 pm*



12:00 pm, Room 400A

## Lunch & Learn panel: Agroforestry challenges for a new generation of scientists

The Lunch & Learn panel will allow renowned researchers and professionals who already have a long career behind them, as well as young researchers and professionals starting their own, to share the fruits of their experience with the next generation of scientists.

In this panel, the panelists, who are all people who contribute or have contributed significantly to agroforestry in many different ways, will first present, in a personal way, their professional background, emphasizing what led them to work in agroforestry, the challenges they had to face, their greatest discoveries, their mistakes, too, and how they would foresee their career if they started it today.

Afterwards, the panelists will be invited to answer a few questions from young agroforestry scientists and the entire audience.

### Panelists:

- Christian Dupraz, International Union for Agroforestry,
- P.K.R. Nair, University of Florida,
- Zénabou Segda, Women Environmental, Programme Burkina,
- Vivian Valencia, Wageningen University and Research,
- Harry Greene, Propagate Ventures.



During the Welcome Reception

Poem

by Laetitia Beaumel

Laetitia Beaumel is a farmer, artist and herbalist. Arrived from Europe in 2007, she has been involved for more than ten years in the artistic landscape of Quebec and Chaudière-Appalaches by participating in several collective projects (*Migration, Cosmogonie des corps*) and by investing herself both in teaching and in cultural mediation. Stimulated by her dual culture and multifaceted life, Laetitia Beaumel is passionate about interdisciplinary and intersectoral dialogue. She is currently pursuing a tailor-made doctorate in literature, music and agriculture at Université Laval with the support of the Social Sciences and Humanities Research Council of Canada and the Fonds de recherche du Québec – Société et Culture, focusing closely on culture-agriculture relationships. Co-founder of *NOUAISONS*, a creative residency program in rural areas, she also gave birth, in early 2020, to *L'Écume*, an eco-responsible publishing house.

Latest published work (excluding collectives): *Chambre claires, Hamac* (Montréal), 2021.

During the Closing Session

Slam

by Léo Coupal

Léo Coupal is a multidisciplinary artist from Quebec. Follower of hiphop culture and break dancer, it was at the age of 15 that he developed a passion for poetry and orality. In 2016, he joined the Quebec slam scene and won the national *Grand Slam*. In 2017, he represented Quebec at the *Coupe du monde de slam de poésie* in Paris and placed fifth there. In March 2021, he won first prize in the eloquence contest *Délie ta langue!* While working on various artistic projects, he continues to develop his personal practice and shares his art between schools and events. In dance as in poetry, he meticulously works on rhythm and emphasizes the "flow" of each performance.





1:30 pm

## Parallel Sessions

Room 202

Workshop Québec: see page 44

Room 200A/B

### C3. Transitioning to Biodiversity

Agroecosystems beyond crop production: diverse farming systems of Eastern Himalaya is a repository of range of biodiversity components

\*Bhoj Kumar Acharya, Sikkim University, India

Sarala Khaling, Ashoka Trust for Research in Ecology and the Environment, Eastern Himalaya, India

The agricultural systems are the major part of socio-ecological landscapes and remains the dominant land use form worldwide. Agroecosystems are generally considered as a system for production of crops but recent researches have recognized huge potential of such systems in conserving biodiversity components and, source of variety of ecosystem services. We evaluated the wild biodiversity conservation potentiality of various agroecosystems of Sikkim-Darjeeling Himalayan region using multi-taxa approach. The region is a part of the Eastern Himalaya, and recognized as one of the agro-biodiversity hotspots of India. Using standard sampling techniques applicable for each taxa we recorded a total of 176 species of butterflies, 50 odonates, 20 amphibians, 23 reptiles, 201 birds and 27 species of mammals across diverse agroecosystems which represents around 40% of the species that occur in the region. Additionally, 46 species were federally protected and conservation concern fauna. We observed that the diversity of each taxa in the agroecosystems were either higher or comparable to the nearby forest patches (considered as control sites). The beta diversity between agroecosystems as well as between agroecosystems and nearby forest patches were high reflecting around 50% differences in the community composition between the systems. The major contribution for all taxa was due to turnover components rather than the nestedness components of beta diversity reflecting that the species were being replaced from system to system rather than one system forming the subset of another dominant system. These diverse ecosystems are experiencing various human induced threats, and findings of this study provides an inputs for management and conservation of agroecosystems and associated biodiversity at landscape level in the Eastern Himalayan region and aid in holistic policy formulation. We highlight the importance of adopting land-sharing conservation approach, especially in the low- and mid-hills, to complement the land-sparing framework.

### Hedgerow networks monitoring for adaptive management of biodiversity in France

\*Sophie Morin, Office français de la biodiversité (OFB), France

Loïc Commagnac, French National institute of geographic and forest information (IGN), France

Sylvain Haie, Office français de la biodiversité (OFB), France

Barbara Freidman, Office français de la biodiversité (OFB), France

“Bocage” is a typical Western European landscape consisting in hedgerow networks surrounding agricultural parcels. Bocage are famous for their remarkable biodiversity due to the presence of many different semi-natural elements. Hedgerows have decreased globally in France for several decades and at the same time scientific community has alerted about a decline of agricultural wildlife. To restore biodiversity globally, it is necessary to take into account not only the needs of birds, but also of a diversity of groups such as amphibians, reptiles, bats or insects. OFB and IGN are preparing a national survey program on bocages to identify the most important landscape parameters and the main structures of semi-natural habitats, as hedges, according to their importance for wildlife. These parameters will be monitored in French hedgerow landscapes to evaluate public policies. The project is divided into three phases : 1. Creation of a first geographic layer of hedgerows using data from remote sensing and photointerpretation, 2. Edition of a new map of bocages in France, 3. Development of a field monitoring on bocages with a focus on quantity and quality of hedgerows. The first results are a diversity of maps representing hedgerows density from national to local scales. We have mapped different indices about connectivity of landscapes or representing the amount of closure in bocages in France, in order to analyze their impact on biodiversity. First results help to target degraded landscape, a challenge is to mobilize farmers to restore biodiversity in connection with the practitioners. The first project partners are French Ministry for Agriculture and Food and the French Ministry for an Ecological Transition. Indeed, the program could help to improve local management practices by farmers or collectivities. Long-term perspective of such a national survey program is to generalize adaptative management at landscape scale to restore biodiversity.

### Bird and insect community in different coffee typologies

Alejandra Martínez-Salinas, CATIE - Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica

Alejandra Ospina, CATIE, Costa Rica

Fernando Casanoves, CATIE, Costa Rica

Eduardo Corrales, CATIE - Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica

Sergio González-Mollinedo, Universidad del Valle de Guatemala, Guatemala

Erick López de Paz, Universidad del Valle de Guatemala, Guatemala

Jeremy Haggard, University of Greenwich, United Kingdom

Coffee is one of the most important crops across the world's tropical regions because of its economic value, contributions to biodiversity conservation, and cultural linkages. During the years 2019 to 2021 we visited 164 coffee farms distributed across all major coffee producing regions of Guatemala (79) and Costa Rica (85). We used point counts and pan traps to characterize the bird and insect communities present in coffee systems under different strategies of agronomic management. Biophysical and socioeconomic data was collected to further characterize the systems and construct farm typologies. We explored relationships between bird and insect richness, abundance, diversity, and farm typologies in both countries. Bird species richness from both Guatemala and Costa Rica was greater than 170 species each and over 300 species when combined, the community was dominated by insectivorous species. In terms of the insect community, the order

Diptera (true flies) was dominant in both Guatemala and Costa Rica, followed by Coleoptera (e.g., beetles), Hymenoptera (e.g., bees, wasps, ants, etc.) and Hemiptera (e.g., cicadas, bed bugs, etc.) which together with Diptera represented the most abundant orders in both countries. Farm typologies were significant at predicting changes in mean bird species richness and Shannon index, mean insect family richness and Simpson index but only for Costa Rica. Other variables such as the percentage of open sky and flower intensity on the herbaceous strata were significant at predicting changes on the mean insect Simpson index. Farm typologies failed to predict changes on variables related to the bird and insect community in Guatemala, but we are currently exploring relationships with other biophysical variables. Coffee systems in both countries hosted a diverse bird and insect community.

Room 301A

## E1. Transitioning to Food Security and Health

### Growing horticultural crops within agroforestry systems: state of the art and perspectives

\*Damien Beillouin, CIRAD, France

Anna Delfosse, CIRAD

Elena Diez, CIRAD, Spain

Sarah Jones, Bioversity, France

In numerous traditional agriculture systems, fruit and vegetables are grown near or under trees. These systems could play a particularly important role for food security, but could also benefit biodiversity and enhance the provision of ecosystem services such as carbon storage. Yet, to date, no study has attempted to provide a comprehensive systematic synthesis of the characteristics and performance of horticultural crops grown in agroforestry systems. To understand the current state of evidence, we systematically searched for studies from around the globe documenting the performance of horticultural-agroforestry systems (HAFS) based on field experiments. We identified and characterised the results of 1024 individual field experiments conducted from 1982 to 2021 in 68 countries across the 6 continents. The majority of studies represent HAFS in India, China and Brazil, while Europe and North America together represent less than 11 % of studies. The HAFS collated include a high diversity of complexity in term of number of cultivated species. For example, we identified 275 horticultural species, including 86 annual and 189 perennials. Tree and crops were mostly arranged in alley cropping systems in the HAFS represented in the database, especially in Europe and North America. Relatively few studies focus on homegardens or multistrata systems, despite these arrangements forming the basis of food security for tens of thousands of farmers. We found that three variables are more frequently investigated in studies on HAFS: yield (56% of the outcomes reported), soil quality (25%) and biodiversity (8%). Socio-economic parameters (e.g., farmer well-being, market access, profitability) were rarely investigated. Our study highlights the diversity of HAFS and shows that large knowledge gaps exist especially for more complex agroforestry systems. We call for more extensive and multi-criteria evaluations of traditional horticultural agroforestry systems.

### Conservation of at-risk medicinal forest herbs: sustainable harvest and propagation of goldenseal in the Appalachian Mountains

\*Katie Commender, Appalachian Sustainable Development, United States

Christine Small, Radford University, United States

The future of the herbal products industry, and health of our forests, depends on sustainable sourcing of medicinal plants. Many forest herbs have been collected for centuries for income and medicinal properties, yet our understanding of harvest impacts is limited. Goldenseal (*Hydrastis canadensis*) is a long-lived deciduous forest herb used for inflammation, digestion, and immunity. Increasing demand and unsustainable harvesting practices have contributed to declines of this important non-timber forest product and its listing as globally vulnerable. The objectives of our 5-year study are to examine: 1) effects of experimental harvests on naturally-occurring goldenseal populations; and 2) success of rhizome propagation, to improve root production and forest farming practices. Sixty-seven study plots (1 m<sup>2</sup>) were established in three naturally occurring goldenseal populations in KY and OH. In each plot, goldenseal density, plant height, leaf size, and reproductive status were recorded, and experimental harvests (0%, 10%, 30%, or 50% removal) conducted. Harvested rhizomes (n = 504) were transplanted into cultivation plots or beds to monitor regrowth across the study period. Study sites differed in goldenseal density (June 2021: 52-114 plants/m<sup>2</sup>) and plant size (Table 1), and showed significant declines (47.6-98.3%) from early- to late-summer 2021 due to seasonal plant senescence. Results from the first year of this study will be used to better understand goldenseal population recovery and sustainable harvest levels relative to harvest intensity, initial plant size, population density, and season of harvest, and to assess rhizome propagation as a sustainable management practice for this and other medicinal forest herbs. With thousands of pounds of goldenseal required by herbal products companies annually to meet growing demand, there is a critical need for sustainable sourcing. This project will inform best harvest practices to sustain the future of goldenseal.

### Different agroforestry designs for diversified organic cocoa production cocoa and by-crop yield development in 11 years of a long-term trial

\*Johanna Rüegg, Research institute of organic agriculture FiBL, Switzerland

Laura Armengot, Research Institute of Organic Agriculture FiBL, Switzerland

Joachim Milz, Fundacion Ecotop, Bolivia

Ulf Schneidewind, Ecotop Foundation, Bolivia

Monika Schneider, Research Institute of Organic Agriculture FiBL, Switzerland

Agroforestry systems for cocoa production are commonly promoted for biodiversity conservation, climate change mitigation and adaptation as well as for food security and risk mitigation. Generally, these systems include timber, legume or fruit trees. Successional or dynamic agroforestry systems represent a special type of design and management approach, using high densities and diversity of trees and crops occupying different strata and with varying life cycles. Here we present results on absolute and potential yields of 3 organic cocoa production systems entering the mature stage from a long-term trial in Bolivia: A complex successional dynamic agroforestry system (SAFS), a simpler but diversified agroforestry system (AF ORG) and a cocoa monoculture (MONO ORG). Cocoa yields were highest in MONO ORG, followed by the AF ORG, and lowest in SAFS. Total system yields in both types of agroforestry systems (dry matter) were 3.5 to 4 times higher than in monocultures over the 11 years. This was mainly due to banana production in AF ORG and from a multitude of by-crops in SAFS. In mature SAFS peach palm was the by-crop with the highest dry matter production. The results demonstrate how different crops can be associated with cocoa while still reaching elevated cocoa yields. The potential of agroforestry systems to sustainably intensify production on one surface is high and could still be optimised with the use of improved and locally selected varieties of cocoa and fruit trees. Different designs of agroforestry systems can contribute to diversification of diets and incomes of producing families and regions.

**Agroforestry practices and their contribution to food security for coffee growers in the Peruvian Amazon**

Olivier Deheuvels, CIRAD, Dominican Republic

Ariel Kedy Chichipe Puscan, IIAP, Peru

Geidy Yecenia Jimenez Yoplac, IIN, Peru

Pamela Katic, NRI, United Kingdom

**\*Sabine Mercier, IIN, Peru**

High levels of food insecurity persist amongst indigenous peoples in the Peruvian Amazon. Over 50% of the children under 5 years old suffer from chronic undernutrition and anemia, far above the national averages of respectively 13% and 34%. The health systems of these populations are based on high native plant and animal biodiversity that provides resources for nutrition and health. Agroforestry practices, defined as the association of crops or animals with ligneous perennials to enhance ecosystem services, are used by these populations because they are closer to traditional indigenous ways of life, as they support high levels of biodiversity. In the Peruvian department of Amazonas, we surveyed 225 farmers and their families in a coffee growing area where agroforestry practices are dominant and distributed along a gradient from the main city. Our objective was to understand how farming systems contribute to food security, and how this contribution could be affected by the accessibility of imported goods. We clustered these families based on their land uses, agroforestry practices and distance to the main city. The agricultural products from each land use were identified and their nutritional value was assessed. The overall nutritional diversity of these products was compared among farm clusters and along the gradient. We found that farm practices and farmers' diet significantly change when access to imported goods is reduced. Agroforestry systems play a key role in providing a diversity of edible products. In particular the choices of cultivated plants and cattle species consistently changed along the gradient, suggesting an adaptive strategy for providing alternative food products when imported goods are not accessible. Based on these results, a complementary ongoing study will allow to determine the contribution of these products to the everyday diet of the families.

**Farmers' Representative in this session: Isabelle Ahou Fram Tano, Ivory Coast**

Room 204B

**F2. Transitioning to a Viable Economy****Which cocoa agroforestry for which timber value chains? Listening to farmers of Côte d'Ivoire**

Brieuc Plas, Private individual, Belgium

**\*François Ruf, CIRAD, Ivory Coast**

In the early 2000s, in continuity with the universal history of this commodity, the cocoa production centers of Côte d'Ivoire moved to new areas, with the last classified forests and secondary forests of the rural domain, particularly in the Man Region, becoming the country's new cacao belt. But in a break with the west-african history of exclusion of smallholders from the timber market, an informal timber economy is also developing in Côte d'Ivoire, especially in this Man region. What role can these farmers' strategies play in "sustainable" agroforestry, combining the cocoa and timber value chains? Our

study starts with smallholders' practices and analyzes the modalities of timber reappropriation as well as their implications in terms of exhaustion or preservation of the wood resource. The fieldwork was carried out from February to May 2020 in three villages in the department of Man. Fifty semi-structured interviews were conducted with producers who are members of an agricultural cooperative (31), customary authorities (10), local and regional authorities (3), illegal sawyers and charcoal burners (4) and sawmills (2) established in the area. Twenty-eight botanical inventories were conducted in cocoa farms covering a total of 18 hectares. In coherence with previous field works in Ghana, the first major result is that farmers' agroforestry strategy highly prioritize revenues, not ecological services to cocoa. They retain trees for uses mainly unrelated to cocoa production. The second major result is that this strategy is really implemented as demonstrated by the significant presence of timber trees in cocoa farms in this region, owing to the development of local/informal timber industry. This practical and concrete self-reintegration of cocoa farmers into the timber markets proves to be a necessary condition for so-called "sustainable" cocoa, and as a corollary to a sustainable timber sector that is evolving and needs recognition.

### Charcoal and wood extraction are threats to Luwero Uganda's agroforestry systems

**\*Cory Whitney, University of Bonn, Germany**

John Tabuti, Makerere University, Uganda

David Mfitumukiza, Makerere University, Uganda

Anke Barahukwa, Makerere University, Uganda

Derick Kisegu, Makerere University, Uganda

Fatuma Mutesi, Makerere University, Uganda

Agroforestry farms in Luwero Uganda are very diverse. The region is home to many ethnic groups with diverse cultures and diverse agroforestry systems that provide livelihoods to local communities. The region is also home to both rich and fragile biodiversity, with several forest reserves and wetlands. These are supported by the surrounding agroforestry systems which act as a buffer while also providing year-round food supply. However, Luwero also has high levels of poverty and is located just 75 kilometres north of Kampala. The markets of that city are a major draw for products from Luwero, leading to the cutting of trees for firewood, charcoal and timber and clearing of land for commercial agricultural plantations (mainly pineapple). Weak rules and legislation together and a lack of effort for replanting trees and better roads and communication have led to the loss of trees across agroforestry systems of the region. We sought to better understand the trends and drivers of loss of trees in Luwero. We carried out fieldwork in Luwero through focus group discussions with community members and farmers together with local officials. These experts identified interventions to stop the loss of tree cover in the region, including introducing affordable alternatives to firewood and charcoal (i.e. briquettes, solar cookers) and promotion of alternative sources of income to charcoal burning. They further identified the need to raise awareness about the importance of trees and the dangers of clearing trees. They pointed out the need for stronger rules to deter deforestation activities as well as promotion of agroforestry-reforestation (i.e. give tree seedlings to farmers and offer technical support to follow up with these farmers and give advice). Interventions to promote the importance of agroforestry and planting trees could and sensitize communities to the issue and help Luwero maintain tree cover.

### Profitable agroforestry systems: the successful case of Brazilian rosewood reforestation in the Peruvian Amazon

**\*Robin Van Loon, Camino Verde, Peru**

Elisabeth Lagneaux, Camino Verde, Peru

In the Peruvian Amazon, small-scale migratory farming represents a significant driver for deforestation. Smallholders convert primary forest to annual crops, a strategy which often fails to provide their household with sufficient income, forcing them to expand their cultivated area further each year. Agroforestry can allow the replacement of slash-and-burn cycles with perennial productive systems, providing obvious ecological benefits. Nevertheless, socio-economic impacts are less straightforward and depend on local variables, often hindering the upscaling of agroforestry adoption. Consequently, financially successful agroforestry systems suited to smallholder farmers in remote areas of the Amazon are still lacking. The non-profit organization Camino Verde is aiming to address this issue by designing, testing, and promoting innovative, diverse, and profitable agroforestry systems. In this presentation, we will share about the experience we gained from working with 106 families from native communities in Loreto, Peru, with whom we installed such systems based on Brazilian rosewood (*Aniba rosaeodora*), an endangered species that was historically depredated for its highly valued essential oil. Our work promotes the reforestation of the species and its sustainable harvest through branch pruning. The development of a transparent Rosewood essential oil supply chain currently allows six pilot-families to receive a monthly income from the selling of biomass. A parcel containing 100 rosewood trees at 8 years of age can provide farmers with 150 PEN (Peruvian currency) monthly, whereas only 50 trees at 15 years of age can provide double that income. We will discuss these encouraging results, the recent upscaling of this activity to five additional native communities and our recommendations for the use of aromatic species to increase the financial sustainability of agroforestry systems in the Amazon.

### Non-destructive assessment of pruning treatments in agroforestry systems

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Werner Mbong, Department of Forest and Wood Science, Stellenbosch University, South Africa

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Jonathan P. Sheppard, University of Freiburg, Germany

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Hans-Peter Kahle, University of Freiburg, Germany

Artificial pruning of agroforestry trees has the potential to generate considerable amounts of lignocellulosic biomass, which is often not quantified. Such a biomass source provides the opportunity for woody biomass production without the need of felling trees. In this study, we assess the actual woody structure of a Namibian silvopastoral system in the African Savannah ecoregion, by applying terrestrial LiDAR technology and modelling tree structure using Quantitative Structure Models (QSMs). The stand displayed an overall tree density of 144 trees ha<sup>-1</sup> and dominated by members of the Fabaceae family, namely, *Burkea africana* (50%,  $\pm 72$  trees ha<sup>-1</sup>); *Pterocarpus angolensis* (33%;  $\pm 48$  trees ha<sup>-1</sup>); *Guibourtia coleosperma* (11%;  $\pm 16$  trees ha<sup>-1</sup>) and other tree species (6%; 8 trees ha<sup>-1</sup>). The 3D data (point clouds) of individual trees was used for estimating tree volume. Following this, we determined five different sets of criteria for simulating pruning treatments with the aim to explore the possibilities of wood provision. We evaluated the potential pruning yields (residues/waste) and the types of assortments produced (fuelwood, fencing poles, housing wood and carving wood) while also assessing the remaining woody biomass components in-situ. We discuss the advantages and disadvantages of each applied harvesting treatment, including stand conditions and potential implications on the health of the remaining trees. We found a great variability of woody structures in the studied stand, while pruning yields are compared to the other common agroforestry systems where they have been quantified by destructive methods. The partitioning of woody structures and the utilisation of pruning simulations are valuable tools to support the planning and design of tending and harvesting operations in agroforestry systems aiming for biomass utilisation, while maintaining the multiple functions of the trees.



Farmer's video: agroforestry in Brazil

Room 301B

### H3. Transitioning to a Viable Development

Mapping past and present trends in heavily intervened farming systems in the Peruvian Amazon

\*Elisabeth Lagneaux, Wageningen University, Netherlands

Katrien Descheemaeker, Wageningen University, Netherlands

Daniel Callo-Concha, University Koblenz-Landau, Germany

Erika Speelman, Wageningen University and Research, Netherlands

The Peruvian department Madre de Dios was, until recently, relatively isolated and therefore deforestation remained low. However, the building of the Interoceanic Highway has attracted a variety of stakeholders with diverse visions for the region's future, e.g., environmental conservation, private profit, regional development and carbon credits. In particular, farming systems are currently at the center of a public strategy aiming to develop agriculture to counter illegal land uses such as gold mining. Yet, there are few studies on the local farming systems and little is known about farmers' preferences. This study aims to provide a historical contextualization of current trends in the farming systems and to map local stakeholders' perceptions of interventions on these systems. To do so, we use the panarchy and adaptive cycle heuristics to explore changes in land-use since 1850, and Fuzzy-Cognitive Mapping to understand the current farming systems and the multiple actors that evolve within it. We found that most farmers are settlers who arrived during relatively recent waves of immigration. As a result, farming systems are located on the first stage of the adaptive cycle (exploitation phase) and evolving fast. Initially migratory, many farmers started planting perennial plants as a result of programs promoting agroforestry since the 1990s. Today, such programs are growing in number and could significantly impact smallholder farmers' experiences and the diversity and resilience of their farms. Often promoted under the banner of agroforestry they do, in some cases, also promote low-diversity farming systems based on single cash crops. This study revealed how local stakeholders perceive such interventions, and how this perception differs between smallholder farmers and decision-makers within governmental or non-profit programs. Based on this information, agroforestry projects can be attuned to farmers' preferences, which will in turn facilitate the adoption of promoted practices.

Supporting agroforestry innovations with holistic, decision-focused modelling: concept

\*Eike Luedeling, University of Bonn, Germany

Katja Schiffrers, University of Bonn, Germany

Hoa Do, University of Bonn, Germany

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Cory Whitney, University of Bonn, Germany

Agroforestry systems are complex and therefore difficult to model. Attempts at developing comprehensive system models have usually produced complicated, data-hungry frameworks that are difficult to apply, especially where the respective agroforestry system is not yet in place. Such models have struggled to include the host of institutional, biophysical and economic barriers that agroforestry pioneers are confronted with. These shortcomings have limited the potential of agroforestry models to support real-life decisions on agroforestry innovations. We present a novel approach to supporting agroforestry decisions, based on the principles of decision analysis, an interdisciplinary research methodology that aims to provide the best possible advice to decision-makers based on the current state of knowledge. Decision analysis is designed to include all important aspects of a decision and all relevant uncertainties, using all available sources of information. It is capable of comprehensively covering the entire context, within which decisions on complex systems are made. Here we present the results of three recent decision analysis models that supported agroforestry decisions, on agroforestry adoption by smallholder farmers in Vietnam, on the viability of earning carbon credits through an agroforestry scheme in Costa Rica and on new agroforestry initiatives in Germany. In all cases, decision models were developed through participatory modeling, and probabilistic simulations of the relative merits of each agroforestry option were elaborated. When comprehensively evaluating the multiple benefits of agroforestry, tree-based systems usually appeared preferable to systems without trees. However, decision analysis often identified critical knowledge gaps related, for instance, to the value of particular benefits or to farmers' time preference. Based on such guidance, critical knowledge limitations can be pinpointed and addressed through further research. While decision analysis only generates coarse forecasts, these are often sufficient for clearly identifying preferable courses of action, offering actionable advice to decision-makers considering the adoption of innovative agroforestry options.

### Supporting agroforestry innovations with holistic, decision-focused modelling: case studies

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Agroforestry systems are complex and therefore difficult to model. Attempts at developing comprehensive system models have usually produced complicated, data-hungry frameworks that are difficult to apply, especially where the respective agroforestry system is not yet in place. Such models have struggled to include the host of institutional, biophysical and economic barriers that agroforestry pioneers are confronted with. These shortcomings have limited the potential of agroforestry models to support real-life decisions on agroforestry innovations. We present a novel approach to supporting agroforestry decisions, based on the principles of decision analysis, an interdisciplinary research methodology that aims to provide the best possible advice to decision-makers based on the current state of knowledge. Decision analysis is designed to include all important aspects of a decision and all relevant uncertainties, using all available sources of information. It is capable of comprehensively covering the entire context, within which decisions on complex systems are made. Here we present the results of three recent decision analysis models that supported agroforestry decisions, on agroforestry adoption by smallholder farmers in Vietnam, on the viability of earning carbon credits through an agroforestry scheme in Costa Rica and on new agroforestry initiatives in Germany. In all cases, decision models were developed through participatory modeling, and probabilistic simulations of the relative merits of each agroforestry option were elaborated. When comprehensively evaluating the multiple benefits of agroforestry, tree-based systems usually appeared preferable to systems without trees. However, decision analysis often identified critical knowledge gaps related, for instance, to the value of particular benefits or to farmers' time preference. Based on such guidance, critical knowledge limitations can be

pinpointed and addressed through further research. While decision analysis only generates coarse forecasts, these are often sufficient for clearly identifying preferable courses of action, offering actionable advice to decision-makers considering the adoption of innovative agroforestry options.

### Relevance of the biocultural diversity concept for agroforestry research

\*Andréanne Lavoie, Département de phytologie, Université Laval, Canada

Alain Olivier, Université Laval, Canada

Agroforestry research recognizes and emphasizes the importance of diversity in agroforestry systems, in terms of structures, species, varieties, functions, or services. However, most researchers have paid little attention to their historical, cultural, and social forms. Yet the concepts we use to define and characterize agroecosystems should reflect their overall complexity, including biocultural diversity. Among other benefits, this concept, which considers the diversity of life in all its manifestations and interactions –biological, cultural, and linguistic– may help agroforestry research put farmers at the center of its approaches and recognize their essential role in conserving agroecosystems in all their diversity. Biocultural diversity could transform the way agroforestry research approaches the management and conservation of agroforestry systems, emphasizing the importance of empirical and farmer-based knowledge, and broader scales of analysis. This would also help to build bridges to more holistic visions of agriculture, such as multifunctional agriculture and agroecology, which recognize the importance of paying attention to the social and cultural aspects in agriculture and the food system in general. In contrast to agro-industrial monocultures, traditional agroforestry and more complex agroecosystems are contextual approaches based on interactions between the natural landscape, its life forms, the climate, and cultural aspects that have influenced the way farmers have planned and cultivated these systems, bringing to new built landscapes. While human cultures affect agroecosystems, the environment also conditions agricultural practices, crops, decisions, and livelihoods. We are thus dealing with co-evolutionary systems where each component adapts to the others over generations. Such ways of producing food and other useful products, and more broadly living off the land, promote the adaptation and resilience of farmers, as well as of their practices, varieties, and systems, to the land and its prerogatives. The transition to more sustainable food systems also requires a revision of our concepts to achieve this.

### Can digital land suitability mapping enhance conventional land-use analysis of smallholder farming systems in upland watersheds in Southeast Asia?

\*Caroline Piñon, University of the Philippines Los Baños, Philippines

\*Anthony Ringrose-Voase, Commonwealth Scientific and Industrial Research Organization, Australia

Wendy Merritt, Fenner School of Environment and Society, The Australian National University, Australia

Upland watersheds in Southeast Asia are hampered with global and regional issues such as poverty, food security, land and water degradation, climate change and others. Among other site-specific and context-based information, detailed accurate spatial data is needed to develop and implement sustainable land-use and management strategies. Quantifying land-use and crop mismatch through household survey results is not a widely used technique. Issues around land-use crops have been raised but without evidence for policymakers to focus; hence public policy remains limited. This paper explores the usefulness of integrating digital soil mapping (DSM) in crop suitability with that of a conventional household survey, utilizing an example of the causality of smallholders' current and preferred land-use and crop production. It uses a mixed method approach through survey-data on current and preferred land-use and crops of smallholder farmers in the Cabulig

Watershed, southern Philippines. These were supplemented by narrative-based data through key informant interviews and farmer group discussions. Farmers' land-use and crop preference were integrated and extrapolated in the DSM-based crop suitability maps developed by the ACIAR-CSIRO for the watershed. Results show that while many smallholder farmers are practicing agroforestry and tree-based land-use, monocropping farming systems are increasingly practiced. These are practiced in inappropriate locations in the watershed; while most crops are found unsuitable to where these are planted. Farmers' land-use and crop preferences are also towards non tree based. There is a scale of biophysical mismatch on farmers' current and preferred land-use and crops, which in turn requires scale to address the problem. Applying DSM-based suitability mapping on survey-data of farmers' actual and preferred land-use and crops provides robust information in assessing their suitability and the scale of issues surrounding these. Considering and understanding farmers' current and preferred land-use and crops, and consequently showing their suitability in maps is visually valuable in providing policymakers choices to focus and prioritize areas for policy interventions.

Room 203

### L3. Which Agroforestry for Commercial Perennial Crops and Trees?

Increasing crop diversity to increase economic and environmental efficiency in coffee and pepper farming systems in Vietnam

\*Clément Rigal, CIRAD, France

Long Chau Thi Minh, WASI, Vietnam

Tuan Dong Minh, ICRAF, Vietnam

Cuong Vo Chi, PRDC, Vietnam

Context: In the Central Highlands in Vietnam, farmers often rapidly reshape their farming systems to adjust to price fluctuations and government incentives. This explains the rapid emergence of Robusta coffee in the 80s and 90s, followed by the expansion of black pepper in the 2000s, and of fruit trees (durian, avocado and macadamia trees) in the 2010s. The resulting mosaic of farming systems comprises monoculture plots as well as agroforestry plots, where coffee is intercropped with pepper and/or fruit trees. Due to high levels of inputs, yields are among the highest worldwide. On the other hand, these intensive farming systems cause in numerous environmental degradations and result in low economic efficiency in times of low commodity prices. Objective: This study aims to assess the impact of crop diversification on economic and environmental performances of coffee and pepper farming systems, to guide their transition towards more sustainable farming systems. Method: More than 200 coffee and pepper farmers were interviewed between October and December 2021, representing a diversity of farming systems throughout the three provinces of Dak Lak, Dak Nong and Gia Lai in the Central Highlands. Methods based on envelop analysis will be used to estimate economic and environmental efficiencies of the various farming systems (Ho et al., 2018), and outline the role of diversification in their performances. Results & Discussion: The analysis will allow the identification of optimal crop mixes (% coffee, % pepper, % fruit trees) for economic and/or environmental efficiency. These optimal crop mixes can in turn guide the numerous public and private programs towards adoption of more sustainable farming systems, therefore reducing environmental degradations, lowering financial risks for smallholder farmers, and ensuring the long-term production of coffee and pepper in Vietnam.

### Assessing farmers innovative oil-palm agroforestry systems in the Allada plateau, Southern Benin

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Hervé Nonwègnon Sayimi Aholoukpè, Centre de Recherches Agricoles Plantes Pérennes (CRA-PP), Institut National des Recherches Agricoles du Bénin, Benin

Bernard Barthès, 3 Eco&Sols, Université de Montpellier, CIRAD, INRA, IRD, Montpellier SupAgro, France

Guillaume Lucien Amadji, Faculté des sciences agronomiques/Université d'Abomey-Calavi, Benin

Cathy Clermont-Dauphin, IRD, France

Innovative cropping systems designed and practiced by farmers are considered as a source of ideas and references to improve sustainably the methods of production. Identifying and evaluating innovative cropping systems in rural smallholdings, in order to derive their social, economic and agro-ecological performances, is necessary to model sustainability, upon which this article is contributing. This study is conducted in the southern Benin, where oil palm-based agroforestry systems have been developed in smallholdings, based on the temporary association of oil palm with other crop with multiple uses and functions. We have surveyed 160 farmers in the aim to describe dominant oil palm-based cropping systems, investigate their rationality and evaluate their performances. The evaluation of the cropping systems is based on standardized indicators, but also farmers-led criteria. The findings revealed that 4 systems, differing from their practices and productive objectives, were classified in types of agronomic logics, and have been evaluated. The practices varied markedly in terms of reasons for selection, socioeconomic characteristics of the farmers and the location of the farms. These systems are innovative in the way they use original technical options (such as intercropping, choice of intercrop succession, oil palm fertilization plan). Results showed that the social and economic performances of all the systems were in line with farmers' perceptions. However, where associated crops agro ecological performances fulfill the farmers' objectives, competition that exist between the oil palm and the main intercrops in the most system and may impede the agro-ecological performance of the oil palm. These results are promising given virtuous agro-ecological practices that can be promoted to foster agro-ecological transition in oil palm production. Ultimately, we plead for dissemination of the farmers-led agro-ecological innovations in larger oil palm producing region while designing researches in the way to improve the oil palm agroecological performances when associated with crops.

### The conditions for RAS (Rubber Agroforestry Systems) to emerge? Income diversification and positive environmental externalities for a better farm resilience

\*Eric Penot, CIRAD, France

Benedicte Chambon, CIRAD, Thailand

Background. Some countries have historically developed rubber agroforestry practices: Indonesia, Thailand, Malaysia (as jungle rubber, or later in Sri Lanka, China and India,. Other countries rely entirely on monoculture (Cambodia, Vietnam, Ivory Coast.....). Historically, jungle rubber was the first rubber cropping system very adapted to local conditions in Southeast Asia but with a low productivity (500 kg/ha/year). Since the 1980's Rubber Agroforestry Systems (RAS) are clone based RAS with a high rubber productivity (1300-1800 kg/ha/year) that replace gradually jungle rubber in Indonesia or are being developed beside monocultures. Objective. The objective is to understand why some farmers have adopted agroforestry practices and identify what are the cultural, socio-economic, technical and political conditions necessary for such development. Methods. We explored the existing bibliography in the top ten rubber producing countries and try to find genericity of RAS development. Results. From 1910 to the 1970's, jungle rubber was widely adopted by poor farmers (no improved planting material nor inputs) in Southeast Asia. The implementation of rubber development projects brought in clonal planting material. Low productivity triggered the end of jungle rubber and boosted RAS development with clonal rubber associated

with fruits, timber trees, vegetable, spices, Tea or resins such as Gaharu. Although rubber monoculture became the main rubber cropping system in many countries, some farmers reintroduced agroforestry practices in their rubber plots. Social role of agroforestry products, income diversification and positive externalities on soil, water and biodiversity were the main reasons for RAS adoption thanks to markets access (fruits in Thailand) and the great facility of rubber to be associated with other trees. In countries with no RAS history and where the development of the rubber smallholder sector was strongly linked to the agro-industrial plantations (Cambodia, Ivory Coast), monoculture remains the main cropping pattern preferred by extension, research and private estates. However most farmers with cocoa plot do know about agroforestry practices. Most farmers therefore have no incentives, needs nor previous knowledge on rubber agroforestry systems and they go on with rubber monoculture. Discussion. The main question is how can we boost RAS development knowing that specific socio-economic and political conditions are required. Conclusion. Knowledge about local contexts and historical conditions of emergence are key elements to boost and promote RAS further development. New tools need to be developed and used to encourage the adoption of RAS.

## Oil palm Agroforestry: assessing feasibility and learning from demonstration sites in the Brazilian Amazon

\*Andrew Miccolis , World Agroforestry - CIFOR-ICRAF, Brazil

Jimi Amaral , World Agroforestry - CIFOR-ICRAF, Brazil

Meine van Noordwijk, World Agroforestry - CIFOR-ICRAF, Indonesia

Marcelo Arco-Verde , Embrapa Forests , Brazil

Henrique Marques, World Agroforestry - CIFOR-ICRAF, Brazil

Martin Meier , World Agroforestry - ICRAF , Brazil

Marielos Peña-Claros , Wageningen University and Research , Netherlands

Danae Ma Rozendaal, Wageningen University and Research , Netherlands

Erika Spielman , Wageningen University and Research, Netherlands

Globally, palm oil is mainly produced in monocrop plantations, which can be highly productive but are also associated with negative environmental and mixed livelihoods impacts. While agroforestry systems (AFS) bear a potential for diversifying oil palm plantations, increasing resilience of systems, enhancing environmental benefits and reducing risks to farmers, they have been piloted on a limited scale and only recently been tested in the context of family farmers in Brazil. This study focuses on initial results of co-designed oil palm agroforestry demonstration sites established in 2017/2018 in Tomé Açu, Pará State, Eastern Brazilian Amazon, on 8 farms totaling 16 hectares. Based on an action research approach, it aims to assess the social, financial and environmental feasibility of oil palm agroforestry so as to elicit learning on its potential for scaling, particularly among family farmers. The financial feasibility of seven demonstration sites was assessed through the AMAZONSAFs tool, an excel-based program that enables cash flow analysis and financial projections for 25 years, and the socio-environmental indicators of 8 sites were appraised through a participatory tool called PLANTSAFS. Overall, the systems performed quite well in terms of basic financial indicators (Net Present Value, Payback, Benefit/Cost Ratio, Internal Rate of Return, and Return to Labor), with values comparable or superior to conventional monocrop systems, thus suggesting their financial feasibility. Similarly, ecological indicators (species diversity, abundance, mulch) suggest a high degree of species and functional diversity, although results varied widely depending on the system. Farmer adoption and satisfaction overall were also deemed high. We conclude that while oil palm agroforestry seems attractive to family farmers, no single solution is suitable to all farmers in this region; rather, flexibility and farmer agency in the design process enabled several different plausible options that varied widely in terms of farmer objectives, key crops, and spatial arrangements.

Room 204A

## M1. Which Agroforestry for Integrating Livestock to Trees and Crops?

What forage tree-shrub species are recommended in alley cropping systems under west Asia conditions?

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Sawsan Hassan, CGIAR - ICARDA, Jordan

Alley cropping is an agroforestry practice of planting arable crops between trees or shrubs. The integration of forage tree-shrub species in an alley-cropping system was examined as an approach to mitigate the effects of climate-induced drought, to improve soil quality and to secure better livelihoods for smallholder farmers in West Asia. Forage tree-shrub performance was evaluated in an alley-cropped system using seven leguminous forage species (*Medicago arborea*, *Colutea istria* and *Coronilla glauca*), three *Atriplex* species (*A. canescens*, *A. nummularia*, *A. undulata*) and spineless cactus pear (*Opuntia ficus-indica*) intercropped between annual crops of wheat, vetch and barley at the Mushaqqar Research Station in Jordan. Growth characteristics were measured by monitoring tree-shrub stem diameter, stomatal conductance, plant height and estimating tree-shrub biomass production. The suitability index was based on growth characteristics for each tree-shrub. Results showed that the *Atriplex* species showed a higher suitability index compared to leguminous shrubs and cactus pear. Among the *Atriplex* species, *Atriplex canescens* recorded the highest plant height, stem diameter and estimated biomass production across all three field crops. Leguminous species recorded low biomass productivity at the beginning of summer but with a low suitability index. Despite their vital role in soil nutrient improvement, there were found to be unreliable in providing supplement forage for livestock. The cactus pear recorded a low suitability index and is not recommended. When implementing alley cropping systems, a balance should be considered between high forage biomass shrub species accessible to livestock after harvesting crops and shrubs that enhance soil nutrient status for improving field crop growing conditions.

## The incorporation, management, and opportunity of Fodder Trees in a Forest Garden System

\*Elizabeth Moore, Trees for the Future, United States

Peter Kingori, Trees for the Future, Kenya

## Perceptions, practice, and barriers of woodland silvopasture adoption among Missouri livestock producers and forest landowners

\*Kendra Esparza-Harris, Center for Agroforestry, University of Missouri, United States

Zhen Cai, University of Missouri, United States

Ashley Conway, University of Missouri, United States

Within the Midwest, the state of Missouri ranks among the highest nationally in cattle herd inventory, with 35% of its land area forested. Missouri livestock producers, especially with smaller acreage graze such wooded areas out of necessity, although, unmanaged woodland grazing is discouraged by agriculture and forestry agencies because of potential adverse ecological effects and decreased animal productivity. However, woodland silvopasture has demonstrated the capacity for ecological, economic, and social benefits with integrated and intentional management of tree, forage, and livestock components. Therefore, the project aims to assess the current woodland grazing and silvopasture practices, perceptions, and potential barriers to woodland silvopasture adoption among livestock producers and forested landowners through the dissemination of a Missouri statewide survey. The targeted multi-use survey will be distributed via mail and electronically



in partnership with the Farm Journal, a media organization. Prior to distribution, in-person and virtual focus groups (n = 2) were held to pilot among participants (n = 10) and enhance the survey instrument to ensure applicability. The developed survey elicits the responses of producers' and landowners in the primary topics 1) demographic information to establish elements of land ownership and current grazing management practices, 2) individual's understanding of the definition of woodland silvopasture and 3) characterized perception and barriers to adoption of woodland silvopasture. There is an estimated targeted response rate of 30% for mail, and/or electronic surveys with an additional 15% return rate for "non-response" survey. Categorical responses will be analyzed using SAS 9.4 and will be used to aid in cultivation of a peer-learning network of silvopasture practitioners in Missouri. Furthermore, the project will evoke outcomes to include increased knowledge of silvopasture adoption, management practices, and perceptions among livestock producers for future research advancements.

### Human dimensions of silvopasture in the United States: Perceptions and management reported by farmers and natural resource professionals

Matthew Smith, USDA National Agroforestry Center, United States

\*Gary Bentrup, USDA National Agroforestry Center, United States

Todd Kellerman, USDA National Agroforestry Center, United States

\*Katherine MacFarland, USDA National Agroforestry Center, United States

Richard Straight, USDA National Agroforestry Center, United States

Lord Ameyaw, Nebraska Forest Service, United States

Silvopasture is the deliberate integration of trees, forage, and grazing livestock on the same land. Through careful management, these systems can provide both short- and long-term income to the farmer, while also providing ecosystem services such as climate mitigation and adaptation. Due to these benefits, silvopasture is increasing in the U.S., as evidenced by regional case studies exploring silvopasture adoption. However, many of these case studies are of small sample size, making it difficult to assess whether broader trends exist that may impact silvopasture adoption. To address this issue, we conducted a systematic review of 52 U.S. silvopasture adoption studies spanning from 1983 – 2021. Our objectives were to: 1) understand the primary benefits and challenges being reported by U.S. producers using silvopasture, 2) assess how satisfied producers are with their silvopasture systems, 3) summarize what maintenance and management activities producers are using, 4) assess the primary drivers affecting willingness or intent to adopt silvopasture, and 5) understand how agricultural and resource professionals view silvopasture management. Results indicate that U.S. farmers incorporate silvopastures into their grazing rotation primarily for livestock shade and to diversify farm income, while the primary challenge was lack of information. In relation to management, 98% of farmers reported using rotational grazing and 96% use their silvopastures in combination with paddocks in open pasture. Farmers also reported using a variety of livestock, which included cattle, goats, sheep, chickens, turkeys, horses, bison, pigs, geese, and ducks. Findings from this study demonstrate the great variability of silvopasture systems found across the U.S. and how producers are responding to the threats of a changing climate by creating resilient agroecosystems that diversify income and enhance ecosystem services. Results will also be compared to silvopasture adoption studies from across the world, providing international context.

Farmers' Representative in this session: Justice Zvaita, Zimbabwe

Room 303A

### O3. Agroforestry - an Essential Pillar of Agroecology

Trees outside of forests in agroforestry as natural ecosystem services solutions

\*Valens Uwizeyimana, KU LEUVEN, Belgium

Jean Bosco Nkurikiye, KU LEUVEN, Belgium

Athanase Mukuralinda, World Agroforestry, Rwanda

Bruno Verbist, KU LEUVEN, Belgium

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\*Geneviève Laroche, World Agroforestry, Rwanda

Population growth coupled with a high demand for wood biomass as a source of energy puts pressure on forest resources and resulted in high land degradation and loss of ecosystem services provided by trees. Trees outside the forest in Agroforestry were identified as natural solutions to restore the degraded ecosystem. Agroforestry has been used as an integrated approach towards a sustainable agricultural system by integrating trees on crops and pasture land. Ecosystem services are the results of biodiversity conservation and agroforestry are assumed to deliver a couple of ecosystem services; Nevertheless, there is inadequate literature on ecosystem services provided by trees outside the forest in agroforestry. This paper assesses the ecosystem services (Provisioning, Regulating, Cultural) from agroforestry. A total of 520 farmer plots were selected and distributed randomly in Eastern Province Farmland. A circle plot of 40 m was established and ecosystem services were assessed. results show that trees outside a forest in agroforestry offer multiple ecosystem services based on tree species and agroforestry practices. For the provisioning category; the supply of raw materials was 17.4% while food supply was 3.9%). The Regulating category;(climate regulation 47.4%,Soil erosion 0.2%, Climate regulating 47.4%, Pollination 13.7%). The cultural category(Recreation 2.9%, Spirituality 0.56%, education 0.48%, Aesthetics 0.48). We recommend a participatory approach that considers the farmers' preferences regarding the expected services from planted trees.

Power struggles in accessing the urban environment for the practice of agroecology: a look at compromises by grassroots initiatives in Madrid, Spain

\*Émilie Houde-Tremblay, Université Laval, Canada

Geneviève Cloutier, Université Laval, Canada

Alain Olivier, Université Laval, Canada

While most of the literature about agroecology relates to its mobilization within rural and agrarian contexts, a growing number of actors explicitly engage with this notion within urban landscapes. Little studied, urban agroecological initiatives, including the ones using agroforestry practices, appear as important sites to document how the notion is being used and debated on the ground. Indeed, studies about food movements and initiatives suggest that the urban environment offers ambiguous transformative possibilities. We suggest embracing these ambiguities by focusing on the trade-offs made by social movements to access resources controlled (at least partially) by the urban administration. Using a case study approach, we studied four initiatives in Madrid (two gardens, one food hub and one farmers' market structure) and their wider implementation context. We realized 26 semi-directed interviews, documentary research and more than 100 hours of observations. Here, we particularly focus on the results related to the two gardens. The first includes fruit trees and a nourishing forest, and the second is part of a historic multifunctional farm with grassland and wooded areas. Our research

suggests that initiatives engage with the City of Madrid under diverging framings of agroecology and understandings of the transformation it implies in terms of interactions between human and non-human beings. Initiatives make conscious and strategic compromises to access resources and limit their marginalization, but still struggle to implement a more radical and holistic framing of agroecology or to gain sovereignty over water and soil cycles. Nonetheless, practices of agroecology and agroforestry – by reducing workload or generating collective skills and understandings of ecological dynamics – cultivate a form of "resourcefulness" allowing initiatives to overcome the limits of institutional support. We argue that while we observed dynamics that can be analysed as instrumentalization by institutions through mechanisms of neoliberal urbanism, it coexists with social movement agency.

### Combining participatory research, field experiments, and non-parametric methods for mixed farming and agroforestry development: a pilot study in Tuscany

\*Martina Re, Sant'Anna School of Advanced Studies, Italy

Martina Occelli, Sant'Anna School of Advanced Studies, Italy

Stefano De Leo, Wageningen University, Netherlands

Sara Burbi, Coventry University, United Kingdom

Paolo Barberi, Sant'Anna School of Advanced Studies, Italy

Alberto Mantino, Sant'Anna School of Advanced Studies, Italy

Given the imbalances and lack of sustainability of mainstream industrial agriculture, alternatives to intensive systems must be developed upon scientific evidence, without neglecting the importance of traditional knowledge. Mixed farming (MF) and agroforestry (AF) systems represent two of these alternatives. Diversification of production and integration of resources, characterized by different levels of complexity, represent key aspects of these systems. This study aims to address the key points for further integration of MF and AF into existing agricultural landscapes through a holistic participatory approach, evaluating their sustainability and resilience, within the AGROMIX Horizon 2020 European project (Grant N.862993). An empirical analysis is performed in southern Tuscany, representative of a Mediterranean ecosystem characterised by soil erosion, where traditional agrosilvopastoral practices are slowly disappearing due to rural areas abandonment. Synergies between crop, livestock, and forestry production are inspected in order to assess farming system complexity, integrating them with an investigation into farmers' perceptions of ecosystem services. As agricultural transformation is at the crossroads between economic and life sciences, we use a highly transdisciplinary participatory research approach within a Bayesian Belief Network framework, utilizing fuzzy cognitive maps methodology, on-farm co-designed experiments, trials, surveys, and focus group discussions. Results are abundant and diverse, appealing to a broad range of transdisciplinary researchers as well as policymakers. We identified objective and subjective drivers of the transition towards MF and AF systems through 120 farm surveys. Five different clones of poplars have been planted on two farms to provide fresh herbage during the dry season and will be analyzed for biomass production and nutritional value. Additionally, 25 on-farm fuzzy cognitive maps on erosion risk perception have been created; they indicate that farmers in the area are widely unaware of the risks linked to soil erosion and largely perform soil management practices which exacerbate the phenomenon.

### TAPE for measuring the multidimensional performance of agroforestry

\*Abram Jared Bicksler, Food and Agriculture Organization of the United Nations (FAO), Italy

Mouhamed Rassoul Sy, Food and Agriculture Organization of the United Nations (FAO), Italy

Dario Lucantoni, Food and Agriculture Organization of the United Nations (FAO), Italy

Anne Mottet, FAO, Italy

Agroforestry and agroecology are topics of intense interest that go beyond production to synergistically affect the entirety of the food and agricultural system and elicit transformational changes needed to sustainably feed and nourish people and the planet. Often seen as a production approach that can catalyze with agroecology, agroforestry approaches have been measured in the past using various production, environmental and economics metrics. Rarely have these included multidimensional performance indicators across the spectrum of sustainability to provide a systemic view of the benefits of agroforestry and how it contributes to agroecology. To address this need, FAO, in partnership with many different stakeholders, developed the Tool for Agroecology Performance Evaluation (TAPE), which is a comprehensive tool that aims to measure the multi-dimensional performance of agroecological systems across the different dimensions of sustainability. It applies a stepwise approach at the household/farm level but it also collects information and provides results at a community and territorial scale. To this end, TAPE was utilized in Tanzania with partners on 72 farms for Steps 1 and 2 in 2021. Control and beneficiary farms were compared with the beneficiary farms having been recipients of agroforestry interventions. The results indicate that beneficiary farms performed consistently better for the overall Characterization of Agroecological Transitions (CAET), but in particular for the elements of efficiency, co-creation and sharing of knowledge, recycling, and culture and food traditions. For the step 2, beneficiaries performed better for agrobiodiversity, youth and women's empowerment, reduced input costs, and improved pesticides usage compared to control farms. As CAET scores improved across farms, dietary diversity, soil health, and farm revenues increased while pesticide usage decreased. This research highlights how multidimensional performance tools can continue to showcase the important role that agroforestry plays for agroecology, together advancing sustainable food and agricultural systems.

Farmers' Representative in this session: Erminda Pacheco & Eulogia Isabel Cordoba, Colombia

Farmer's video: agroforestry in Guatemala

Room 304A/B

### Side Event - Agroforestry and Climate Adaptation Policies: Between Potentials and Challenges (FAO)

Increasingly, countries are realizing the benefits that trees can bring to agricultural and pastoral landscapes. Agroforestry provides a unique opportunity to address the climate emergency and biodiversity loss while achieving sustainable development goals and commitments, including food security and nutrition. Despite this cross-cutting potential, agroforestry has not yet been sufficiently

integrated and supported in national and global strategies regarding adaptation to climate change. Through projects from different developing countries, this event examines the opportunities, challenges and issues related to the adoption of agroforestry solutions from the community to the national level.

by Mawa Karambiri, CGIAR ; Jean-Pierre Faye ; Daouda Ngom, Université Cheikh Anta Diop de Dakar ; Maguette Kaire & others.

Language: English

*Coffee break: 3:00 to 3:30 pm*



3:00 pm, Room 400A

## Poster Session 2

All posters will be displayed in the room during all the congress. Two sessions (Monday 3:30 to 5:00 pm and Tuesday 3:00 to 4:30 pm) are also planned in the program so that authors can present their posters in-person and discuss with other participants about them.

Monday's session will be divided into 3 periods of 30 minutes each:

- The first period will be allocated to a free visit of the posters.
- In the second period, half of the authors of posters on the same theme will be divided into small groups and invited to present their poster in turn, for a period of approximately 3 minutes each, in front of the members of their group, to whom will be able to join all the other participants interested in their theme.
- The other half of authors will do the same during the third period.

During the Tuesday session, after a 30-minute free visit, the members of each of the groups will be invited to discuss their theme with each other as part of a cooperative creative workshop.

3:20 to 4:20 pm - Creation time!

All poster presenters will gather at their designated table in the lunchroom, along with the willing congress participants. Volunteers will be in the room to help you in case you have questions.

1. First, you will be invited to briefly discuss about the poster presentations and share what stood out to you: what links do you see, what are the similitudes or differences, the challenges, the drawbacks, the innovations, the inspirations, the gaps? (10 mins)

2. Next, you will choose the question(s) you want to answer among the following (5 mins):

- How do these posters highlight the role of agroforestry in the transition to a viable world?
- What elements or ideas displayed during the poster presentations contribute to the ecological transition?
- What lessons can be learned from the posters to initiate, inspire or orient the transition to a viable world?

3. Then, you will have to illustrate your answer(s) to the chosen question(s) on the paper provided to you, making sure the question(s) are visible. Your illustration can take the form of a concept network, a diagram, a drawing, a word cloud, a mind map, etc. Let your imagination run wild! (20 mins).

4. If you want to contribute to another theme or another table, it's possible! Give your colleagues a low bow and go join the table(s) of your choice.

4:30 pm

## Parallel Sessions

Note: Room 202 starting at 3:30 pm

Workshop Québec: see page 44

Room 200A/B

### C4. Transitioning to Biodiversity

How multifunctional are agroforestry parklands? A landscape scale assessment of multiple ecosystem services from a *F. albida* parkland in Senegal

Louise Leroux, CIRAD, Senegal

\*Cathy Clermont-Dauphin, IRD, France

Moussa Ndienor, ISRA, Senegal

Christophe Jourdan, CIRAD, France

Olivier Roupsard, CIRAD, Senegal

Josiane Seghier, IRD, Burkina Faso

A specific case of agroforestry are *Faidherbia albida* parklands that are widespread in Sub-Saharan Africa. Given its potential to provide a large spectrum of ecosystem services (ES), *F. albida* parklands are now widely recognised as a key option to meet the 2030 UN SDGs. Despite a large body of literature on ES provided by *F. albida* parklands, most evaluations were carried out at the tree scale, and a landscape scale assessment of multiple ES and their interactions is still lacking. Our aim is to fill this gap by providing a first characterization of the spatial supply of multiple ES and their relationships. A case study was conducted in 2019 in the groundnut basin of Senegal. We combined observed data for 11 ES indicators from 136 sampling points with remote sensing-derived data. First, the spatial distribution of each ES supply was modelled using machine learning approaches. The ES indicators were modelled with accuracies ranging from 68% to 96%. We evidenced that the majority of ES indicators remained below ES potential values over the study area by 25% to 50% of suggesting that there is an opportunity for increasing the ES supply in the *F. albida* parkland. Second, combining a scoring approach with a spatial co-occurrence method, we identified the dominant relationships among ES and we analyzed their distributions according to the distance to *F. albida* trees. We showed that losses, synergies and tradeoffs accounted for 41%, 40% and 19% respectively of the dominant relationships. Synergies were predominant between 0-10 m from *F. albida* trees. Above this threshold, synergies started to decrease as one moved away from the trees while the proportion of losses and trade-offs relationships increased. By providing spatially explicit information on multiple ES relationships our results can be helpful for the development of evidence-based policies for scaling up agroforestry parklands and fostering better management of multifunctional landscapes.



### Interacting pest control and pollination services in coffee systems

**\*Alejandra Martínez-Salinas, CATIE, Costa Rica**

Adina Chain-Guadarrama, CATIE - Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica

Natalia Aristizábal, University of Vermont, United States

Sergio Vilchez-Mendoza, CATIE - Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica

Rolando Cerda, CATIE, Costa Rica

Taylor Ricketts, University of Vermont, United States

Biodiversity-mediated ecosystem services (ES) support human well-being, but their values are typically estimated individually. ES are part of complex socio-ecological systems, but we know surprisingly little about how multiple ES interact ecologically and economically. Interactions could be positive (synergy) or negative (trade-offs), with strong implications for management and valuation. Here we evaluate the interactions of two ES, pollination, and pest control, via a factorial field experiment in 30 Costa Rican coffee farms. We found synergistic interactions between these two critical ES to crop production. The combined effects of bees and birds on fruit set, fruit weight, and fruit weight uniformity were greater than their individual effects (Fig. 1). To our knowledge, this represents some of the first experimental evidence at realistic scales of positive interactions among ES. These synergies suggest that assessments of individual ES may underestimate the benefits biodiversity provides to agriculture and human wellbeing. Our field experiments demonstrate that bee pollination and bird pest control services translate directly into monetary benefits to coffee farmers. Excluding both bees and birds resulted in an average yield reduction of 24.7% (equivalent to losing US\$1,066.00/ha). These findings highlight that habitat enhancements to support native biodiversity can have multiple benefits for coffee, a vastly valuable crop that supports rural livelihoods worldwide. Accounting for potential interactions among ES is essential to quantifying their combined ecological and economic value.

### Cocoa agroforestry systems for the conservation of tree species and incomes enhancement in forest-savannah areas and humid forests, Côte d'Ivoire

**\*Constant Yves Adou Yao, UFR Biosciences, University Félix Houphouët-Boigny, Ivory Coast**

Venance-Pâques Gniayou Kouadio, UFR Biosciences, University Félix Houphouët-Boigny, Côte d'Ivoire, Ivory Coast

Affia Sonmia Francia Kossonou, UFR Biosciences, University Félix Houphouët-Boigny, Côte d'Ivoire, Ivory Coast

Bona Antoinette Tokou, UFR Biosciences, University Félix Houphouët-Boigny, Côte d'Ivoire, Ivory Coast

Benjamin Garnier, UFR Biosciences, University Félix Houphouët-Boigny, Côte d'Ivoire, Ivory Coast

Bi Tra Aimé Vroh, UFR Biosciences, University Félix Houphouët-Boigny, Côte d'Ivoire, Ivory Coast

Cocoa production in Côte d'Ivoire is generally based on "full sun" crops. However, the presence of traditional cocoa agroforestry systems (AFSc) has been highlighted in several regions including the Centre, South, Southeast, and Centre-West. The present study aimed to provide information on the conservation of tree species diversity, their biomass, financial profitability, the economic value of non-timber forest products (NTFPs) and the potential economic value of the organic cocoa agroforests in central and Eastern Côte d'Ivoire. Trees species maintained or introduced in the farms have been inventoried in plots of 625 m<sup>2</sup>. A socio-economic survey and direct observations have been carried out among farmers who owned these AFSc types. The results revealed 124 tree species associated to cocoa trees (30 in the centre and 111 in the southeast). Associated species in AFSc of forest-savannah transition area had a density of 71.27 stem.ha<sup>-1</sup> and produced an average biomass of 128.64 tons per hectare. During the dry season in forest-savannah transition area, associated species create a microclimate that protects cocoa trees from water stress. In forest zone, associated woody species in cocoa agroforest presented a density of 128.76 stem.ha<sup>-1</sup> and produced an average biomass of 432.46 tons per hectare, which

were more than three times that found in the transition area. All species encountered in forest-savannah transition area have been indicated by peasant as a source of NTFPs involved in food, medicinal, artisanal, and cultural uses while in forest areas, only 44 of the 111 species listed were cited as those offering various services to peasants. These AFSc are so important that they bring on average of \$607.20 per year to a farmer in forest area and an average of \$382.50 in forest-savannah area. The above results confirmed that cocoa agroforestry systems allow farmers to conserve woody species diversity. These species provide various ecosystem services both carbon sequestration and the provision of livelihoods to local populations.

Farmers' Representative in this session: Emmanuel Kuh, Cameroon

Farmer's video: agroforestry in Brazil

Room 304A/B

### D3. Transitioning to a Viable Climate

Riparian agroforestry systems - the role of biodiversity in soil carbon sequestration

\*Serra-Willow Buchanan, University of Toronto, Canada

Marie Sauvadet, CIRAD, France

Marney Isaac, University of Toronto, Canada

Riparian agroforestry buffers represent unique ecotones within agricultural landscapes which can be managed to improve ecosystem services provisioning. While many riparian buffers are left fallow, there is a growing interest in their agroforestry potential, as the inclusion of trees increases carbon (C) sequestration potential and nutrient cycling. These services are inherently tied to the functional traits of the tree and understorey plant community, yet there is very little information on plant community diversity and its role in soil C storage in these critical transition zones. Drawing on a network of established riparian buffers within southern Ontario, Canada, including a rehabilitated deciduous agroforest, a mature coniferous agroforest and a grassland buffer, we collected litter from plant communities with significantly different leaf trait syndromes for use in a 95-day incubation experiment. We determined the litter vs soil-derived portions of C-CO<sub>2</sub> by analyzing gas samples for CO<sub>2</sub> concentration and  $\delta^{13}\text{C}$  on a Picaro G2131-i. We found significantly different rates of total C-CO<sub>2</sub> between litter treatments. Notably, the agroforestry treatments resulted in lower cumulative C loss over a 95-day incubation period compared to the grassland treatment. The coordination of leaf functional trait syndromes on C loss (litter vs soil derived) and the importance of species mixing in agroforestry systems on C dynamics will be presented. To our knowledge, this is one of the first litter decomposition studies to track soil and litter-derived C using mixed species incubations and provides an important step in understanding critical but unknown aspects of soil C cycling and storage in agroforestry systems of high plant community complexity and diversity.

### Selecting agroforestry plant materials for a changing climate: North American examples

\*Gary Bentrup, USDA National Agroforestry Center, United States

Raju Soolanayakanahally, Agriculture and Agri-Food Canada, Canada

Plant materials are the key building blocks in agroforestry systems, and it is critical to select species that will perform well under a changing climate. This presentation describes two projects being conducted at Agriculture and Agri-Food Canada (AAFC) and the USDA National Agroforestry Center (NAC) to help address these challenges. At AAFC, tree improvement efforts touched many genera and species but focused primarily on the genera of trees (*Populus*, *Salix*, *Fraxinus*, *Quercus*, *Larix*, *Pinus*, *Picea*) and shrubs (*Hippophae*, *Shepherdia*, *Prunus*, *Caragana*). For example, the Agriculture Canada Balsam Poplar (AgCanBaP) program is focused on developing balsam poplar (*Populus balsamifera* L.) materials. Balsam poplar is highly variable and capable of a broad range of adaptive physiological responses to a changing climate. Researchers at AAFC who have advanced genetic improvement on a number of species have also now assembled a balsam poplar collection. The AgCanBaP collection consists of material from throughout North America that provides germplasm for climate change, breeding, and genomic studies. This collection is currently being screened to identify fast-growing selections that have greater C sequestration and biomass yields. NAC has developed an online decision support tool to help producers select better species of trees and shrubs to achieve a suite of user-defined agroforestry purposes. In this tool, over 90 species of trees and shrubs are rated for 14 different purposes in the Great Plains region in the United States. Ratings were developed by considering climatic suitability of each species and plant traits that make a species relatively better (or worse) for each specific purpose. This tool may serve as a template for developing multi-purpose plant decision support tools for other regions. By considering a comprehensive spectrum from developing suitable species selections to delivering plant selection tools, we can make evidence-based decisions for putting the right plants in the right place.

### Analysis of the agroforestry measures in National Adaptation Plans (NAPs)

\*Alexandre Meybeck, CIFOR-ICRAF, Italy

Vincent Gitz, CIFOR-ICRAF, Italy

The NAP process was established in 2010 under the United Nations Framework Convention on Climate Change (UNFCCC) for least developed and other developing countries to identify and address their medium- and long-term adaptation needs. It is now playing an increasing role in the implementation of the NDCs: 98% of the adaptation components of the new and updated NDCs mention the NAP, with 22% as the implementation mechanism or source of information of the NDC. This paper analyzes and categorizes the agroforestry measures and policies mentioned in NAPs in order to propose recommendations to improve the integration of agroforestry in adaptation planning processes. We analyzed the national adaptation plans submitted in English, French or Spanish on NAP Central, the dedicated UNFCCC website by end of October 2021. The analysis was conducted by combining structural analysis, word search and qualitative content analysis of the published documents, using existing classifications of agroforestry measures further refined to be best adapted to the content of the NAPs. Agroforestry is generally covered in the agriculture section of NAPs, with the word itself mentioned in two thirds of them. Most measures are technical, focused on biophysical rather than economic resilience, addressing either a direct climate related risk (wind breaks, shade trees) or a natural resource concern (degraded land, soil erosion, water evaporation). In some countries agroforestry is implicitly covered by broad measures or orientations. Only few mentions are made of the need to adapt agroforestry or tree farming systems. There is limited mention of co-benefits nor of enabling measures. Agroforestry measures in NAPs are often limited to the addition of trees in farming systems to address biophysical threats. They generally lack the systemic approach that would optimize their contribution to adaptation and facilitate their adoption.

## Quantifying system-level carbon sequestration in diverse temperate agro-ecosystem riparian buffers in southern Ontario, Canada

\*Enoch Ofosu, University of Guelph, School of Environmental Science, Canada

Amir Bazrgar, University of Guelph, Canada

Brent Coleman, University of Guelph, School of Environmental Science, Canada

Bill Deen, University of Guelph, Canada

Andrew Gordon, University of Guelph, School of Environmental Science, Canada

Paul Voroney, University of Guelph, Canada

Naresh Thevathasan, University of Guelph, Canada

Riparian buffer systems (RBSs) are capable of sequestering atmospheric CO<sub>2</sub> into stable terrestrial carbon (C) pools. The potential effects of diverse RBSs [tree buffers (99 years) (coniferous (103 years), deciduous (94 years)), grass buffers (35 years), rehabilitated buffers (41 years) and natural forest buffers (156 years)] on terrestrial C stocks (biomass and soil) are not clearly understood. This study therefore, quantified (a) C stocks in various terrestrial C pools of diverse RBSs (soil (0-60 cm) and biomass (above and belowground)), (b) System-level C sequestration potential (SLCSP) (' C stocks) and (c) annual system-level C sequestration potential (annual SLCSP) in southern Ontario, Canada. Results showed significant differences ( $p < 0.05$ ) in C stocks between tree buffers (766 Mg C ha<sup>-1</sup>) and grass buffers (292 Mg C ha<sup>-1</sup>) and between natural forest buffers (936 Mg C ha<sup>-1</sup>) and rehabilitated buffers (596 Mg C ha<sup>-1</sup>), but no significant difference ( $p \geq 0.05$ ) between coniferous buffers (722 Mg C ha<sup>-1</sup>) and deciduous buffers (809 Mg C ha<sup>-1</sup>). Additionally, tree buffers had significantly higher ( $p < 0.05$ ) SLCSP (580 Mg C ha<sup>-1</sup>) than grass buffers (123 Mg C ha<sup>-1</sup>). Natural forest buffers had significantly higher ( $p < 0.05$ ) SLCSP (751 Mg C ha<sup>-1</sup>) than rehabilitated buffers (410 Mg C ha<sup>-1</sup>). Conversely, there was no significant difference ( $p \geq 0.05$ ) in SLCSP between coniferous buffers (570 Mg C ha<sup>-1</sup>) and deciduous buffers (591 Mg C ha<sup>-1</sup>). Further, annual SLCSP was significantly higher ( $p < 0.05$ ) in tree buffers (6 Mg C ha<sup>-1</sup>Y<sup>-1</sup>) than in grass buffers (4 Mg C ha<sup>-1</sup>Y<sup>-1</sup>). Results from this study confirm that the establishment of RBSs as a best management practice (BMP) within Canadian agricultural watersheds can significantly contribute to create new terrestrial C sinks in agricultural ecosystems.

## Co-benefits, trade-offs, and uncertainty: evaluating agroforestry for climate change mitigation using multi-criteria decision analysis

\*Kira Borden, University of Guelph, Canada

Amy Norgaard, British Columbia Ministry of Agriculture, Food and Fisheries, Canada

Carson Li, University of British Columbia, Canada

Sean Smukler, University of British Columbia, Canada

Identifying which management practices to promote for climate change mitigation is complicated. Agroforestry systems are broadly considered to rank highly among a plethora of management practices that can reduce greenhouse gases (GHGs) and provide other ecosystem services. However, costs, regulations, and variable and uncertain GHG reductions can be barriers to implementation. Additionally, the data and circumstances under which management practices are evaluated are rapidly evolving. Thus, decisions by farmers and policy makers for GHG reductions should be both holistic in weighing the costs and benefits as well as flexible and iterative over time. We address these requirements through development of an evidence-based and participatory decision-making framework, based on multi-criteria decision analysis. The framework systematically compares agroforestry and other management practices in their capacity for GHG reductions, environmental co-benefits, and adoptability criteria. We created a flexible, user-friendly tool for ranking performance of management practices across a range of agricultural subsectors. The tool integrates data that we compiled through evidence synthesis,

freely available agricultural statistics, and expert questionnaires. Our tool and analysis notably include estimates of uncertainty, which is essential to gauge the likelihood of an outcome – such as meeting GHG reduction targets – and/or in identifying major gaps in data. We demonstrate this framework using the province of British Columbia, Canada as a case study. We estimate provincial-level GHG reduction potentials and relative performance of a variety of management practices – such as riparian tree planting, cover cropping, and preserving forest. We find agroforestry systems generally rank high but with high uncertainty in carbon sequestration potential. We highlight how participatory decision-making can be strengthened with expert and stakeholder engagement. Ultimately, the framework can complement detailed GHG modelling while providing tangible decision support for climate change mitigation programming that accounts for multifaceted impacts on the environment and farmer.

Room 301A

## E2. Transitioning to Food Security and Health

### Nutritionally Underutilized Species in Ethiopian coffee agroforests: local solutions to local problems

\*Daniel Callo-Concha, Center for Development Research (ZEF), University of Bonn, Germany

Omarsherif Jemal, College of Agriculture and Veterinary Science, Department of Forestry, Arsi University, Ethiopia

Habtemu Seyoum, Ethiopian Institute of Agricultural Research, Ethiopia

Meine van Noordwijk, World Agroforestry (CIFOR-ICRAF), Indonesia

Donatus Nohr, Institute of Nutritional Sciences (140a), University of Hohenheim, Germany

The montane rainforests of southwestern Ethiopia are dominated by highly biodiverse coffee-based agroforestry systems. In the same area, local inhabitants often show high indices of food and nutritional insecurity, as their diets abound in staples but lack of protein and micronutrients. We hypothesize that nutritionally underutilized species (NUS) growing beneath agroforests can contribute to fulfil the local inhabitants' nutritional needs. Hence, we have: (i) identified the NUS growing beneath agroforestry systems; (ii) assessed the nutritional status of local inhabitants; and (iii) analyzed the NUS nutrient values to satisfy the local inhabitants needs. For that we have applied an ethnobotanical household survey to identify existing NUS (n=300), implemented a dietary and biometry assessments in households' sensitive groups, and carried out lab analysis of the nutritional factors of a subset of promising NUS (n=12). We have identified 127 edible species growing under agroforests, 55 were regularly cultivated and 25 qualified as NUS. Although more than four fifths of the population were food secure, 17% of children were chronically stunted, and 50% of all inhabitants suffered of iron deficiency. The NUS analyzed demonstrated been capable to fill the householders unsatisfied nutritional needs. Notable were *Amaranthus graecizans*, *Portulaca oleracea* and *Dioscorea cayenensis* as providers of Ca, Fe and Zn, and the fruit *Rubus apetalus* of provitamin A. Further, the cross-analysis of our data streams showed that the number of species and agroforests storeys were significantly correlated with the household food access security as well as the biometric development of children below 5 years old; and families that practice agroforestry have significantly higher dietary diversity. We conclude that households practicing agroforestry have better nutritional records, especially in the scarcity season; and a number of NUS growing beneath them can provide the nutrients that are needed locally.

### Agroforestry stakes for climbing beans, a sustainable solution for increased yields in semi-arid Rwanda

\*Athanasie Mukuralinda, World Agroforestry, Rwanda

Jean Damascene Ndayambaje, Rwanda Forestry Authority, Rwanda

Elisée Bahati Ntawuhiganayo, World Agroforestry, Rwanda

Jean Claude Bambe, World Agroforestry, Rwanda

Thomas Gakwavu, World Agroforestry, Rwanda

Providence Mujawamaria, World Agroforestry, Rwanda

Valens Uwizeyimana, KU LEUVEN, Belgium

Genevieve Laroche, World Agroforestry, Rwanda

Catherine W. Muthuri, World Agroforestry, Kenya

Bean is a staple food in Eastern Africa and contribute to reduce malnutrition and generate income to farming households particularly in Rwanda. The insufficient availability of reliable stakes for climbing beans has remained a challenge for farming communities, particularly in semi-arid areas, Bugesera, with low tree cover. Farming with trees was identified as a promising solution to address availability of stakes for climbing beans which were reported to produce more than twice compared to bush beans. A study was conducted to compare production of bush and climbing beans using different agroforestry stakes. A total of 103 on-farm, participatory trial plots of 10x10m were established to test the bean production using stakes from nine agroforestry species: *Eucalyptus* sp., *Calliandra calothyrsus*, *Senna spectabilis*, *Vernonia amygdalina*, *Gliricidia sepium*, *Grevillea robusta*, *Lantana camara*, *Markhamia lutea* and *Leucaena diversifolia*. Farmers were scattered across five sectors of Bugesera, Rwanda. Seasonal yields were recorded and compared in the trials with differing types of agroforestry stakes, sites and in relation with the control, bush beans. The results show that during the short rain season (season 2020A), the yield of climbing bean was higher than that of bush bean, except for bean staked with *Lantana camara* that recorded the lowest yield of about 0.65 T ha<sup>-1</sup> that was not different from the yield of bush bean. The highest climbing bean yield was 1.9 T ha<sup>-1</sup>, while the lowest was 0.68 T ha<sup>-1</sup>. During the long rain season (Season 2020B), the highest yields were greater than 1.2 T ha<sup>-1</sup>, while the lowest was less than 1 T ha<sup>-1</sup>. Both *Senna spectabilis* and *Gliricidia sepium* showed higher performances and offered additional advantages in soil fertility amelioration and erosion control. The findings suggest that the yield of climbing beans depends on the type of agroforestry stakes being used.

### The Forest Garden Approach: Food Security and Dietary Diversity Impacts

\*Andrew Zacharias, Trees for the Future, United States

Background: The Forest Garden model has been the core methodology of Trees for the Future's training programs implemented with 35,000 smallholder farmers in East and West Africa over the last 5 years. Typically designed on 1-2 acres, Forest Gardens offer farmers a small-scale diversified agroforestry system that meets household and market needs. Objectives: This presentation will share the results of multi-year project implementation data with regard to its impact on smallholder farmer family food security and provide the opportunity to discuss best practices for integrating food security into agroforestry data collection and program implementation. Methods: TREES measures household diet diversity with the survey consists of the Household Dietary Diversity Score (HDDS) developed by the U. S. Agency for International Development (USAID) and measures household food security using the Household Food Insecurity Access Score (HFIAS) developed by the Food and Agriculture Organization (FAO). Annual data collection from the program will provide data for the analysis. Results: A 4-year analysis of the Forest Garden programs found that on an average, the number of families reporting high diet diversity in their Forest Gardens increased by 44% and, notably, families reporting low diet diversity fell to zero. With regard to food security and HFIAS data, over the four-year survey period, TREES recorded a 33.23% drop in

severely food insecure families and a 44% increase in food secure families. Discussion: TREES data collection has shown that the Forest Garden Approach is a viable solution to helping communities achieve food security and can serve as a best practice for similar organizations seeking to integrate food security into other projects and research frameworks. Conclusion: Agroforestry projects can and should incorporate food security data collection. This case study provides some tools and best practices to track and report on the integration of food security, agriculture and human health.

### Measuring resilience capacity of Indigenous Peoples food systems: what role for agroforestry?

\*Pamela Katic, Natural Resources Institute (NRI), University of Greenwich, United Kingdom

Maria Ximena Flores Rojas, IIN, Peru

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Geidy Yecenia Jimenez Yoplac, IIN, Peru

Sabine Mercier, IIN, Peru

In many Indigenous Peoples' food systems across the world, agroforestry is widely practised and contributes to resilient diets, resilient cultures, and resilient ecosystems. For cultures of Indigenous Peoples to have survived for thousands of years, their ecosystems and food systems, if intact, are then by definition resilient, while recognizing that change and evolution are regularly experienced in natural ecosystems. However, because of globalized food markets, growing populations and climatic pressures, the food systems of most Indigenous Peoples today, even those in very remote rural areas, are increasingly composed of a mixture of traditional local foods and foods purchased from commercial outlets, creating an ever-increasing loss of local biodiversity, dietary quality, and food insecurity for these populations. Understanding how Indigenous Peoples perceive resilience of their food systems and the role of agroforestry in building resilience capacity provides a unique view on food system resilience. The purpose of this article is to: (1) describe the development of a multi-dimensional metric of food system resilience capacity which accommodates local-level measurement in the context of broader national and global scale measures; (2) examine the role of agroforestry in the dimensions of such metric; and (3) propose a process that supports indigenous peoples' self-determination over localized progress toward resilient food systems. We illustrate the construction of the metric using a mix of secondary data and primary data (household surveys, biodiversity inventories and ethnographic research) collected in a case study of Indigenous Peoples' food systems in communities of the Peruvian Amazon. Key results include a framework of indicator themes that are anchored in an Indigenous Peoples' led definition of resilience, stable at national and global scales while remaining flexible at the local scale to accommodate contextual needs. We also propose a process for facilitating community-level planning for food system resilience that utilizes this indicator framework.

Farmers' Representative in this session: Kumar Neeraj, India

Farmer's video: agroforestry in Brazil



Room 204B

### F3. Transitioning to a Viable Economy

#### Economic performance of temperate agroforestry systems a scoping review

\*Alma Thiesmeier, Leibniz Centre for Agricultural Landscape Research e.V., Germany

Peter Zander, Leibniz Centre for Agricultural Landscape Research e.V., Germany

Research on temperate agroforestry has gained momentum in recent years due to its potential to simultaneously contribute to climate change mitigation and adaptation. While there exist reviews on their environmental and ecosystem service outcomes, such knowledge synthesis is missing when it comes to their economic performance. This review aims to fill this gap and to identify research gaps using the JBI methodology of scoping reviews after Elm, Schreiber & Haupt (2019). A scoping review protocol was written alongside the review. Preliminary results show frequent employments of capital budgeting and investment planning tools while few studies focus on risk. Under current conditions agroforestry usually generates lower returns than traditional agriculture but higher returns than forestry, though there are exceptions. The difference between the profitability of agroforestry and agricultural land use, however, can be very small, depending on site and management characteristics. Additionally, many studies report that under changing policy or environmental conditions agroforestry might become economically competitive to traditional agriculture. Research is often clustered in specific regions and focuses on agroforestry systems that are traditional for those areas (e.g. Dehesas/Montados). When it comes to risk, only few studies are available. They indicate that agroforestry, against widespread assumptions, might not actually decrease economic risk in most cases and that being locked into an inflexible production system generates its own specific risk. When it comes to climate risk and shocks however, agroforestry but can be effective tool for risk reduction. This allow the preliminary conclusion that agroforestry systems are generally outperformed by traditional agricultural production under current market and climatic conditions which do not internalise environmental externalities. However, since agriculture is a substantial contributor to climate gas emissions, agroforestry's ecosystem service provisioning lends justification for introducing policies that incentivise implementation to bridge the gap in economic performance.

#### Sustainability of an agroforestry system associating medicinal plant crops with commercial woody species: case study in Quebec

\*Marie Dromain, Université Laval, Canada

Jean Arsenault, Agroforestry Farmer, Canada

Alain Olivier, Université Laval, Canada

Medicinal plants, already used by First Nations, have been experiencing a resurgence of interest for several years now. Unfortunately, the growing demand is leading to an increase in harvesting which thus threatens wild populations. Understorey cultivation allows to protect them while offering the owners the opportunity to enhance their forest stands or plantations. However, the lack of technico-economic data on the sustainability of such agroforestry system slows down its adoption. We have therefore performed, together with a producer in Lévis, Quebec, Canada, a case study on an agroforestry system combining noble hardwoods with medicinal plants such as Goldenseal (*Hydrastis canadensis*), Wild Ginger (*Asarum canadense*), Bloodroot (*Sanguinaria canadensis*) or American Ginseng (*Panax quinquefolius*). The aim of the study was to evaluate its economic sustainability in order to support forest or plantation owners interested in growing medicinal plants under forest cover. The data collected between 2007 and 2014, and then in 2021, included the number of working hours and their distribution over a year for each type of work associated with the different herbaceous crops and woody species,

as well as yield, expenses, and income. These data allowed us to study the annual profitability of the whole site as well as per m<sup>2</sup> for each cultivated species. The results show that the combination of medicinal shade plants and commercial trees provides a significant extra income to the producer on a small area carefully cultivated. However, this income varies widely by species, ranging from 25 CA\$/hour for Bloodroot to 85 CA\$/hour for Wild Ginger. Although they come from a single expert producer, the results highlight the importance of the knowledge and know-how acquired by producers and the need to disseminate them in order to allow the deployment of this type of agroforestry system for which scientific knowledge remains scattered.

### The Appalachian harvest herb hub: creating a sustainable herbal economy in the Appalachian Mountains

\*Katie Commender, Appalachian Sustainable Development, United States

It is estimated that over one-half of native U.S. medicinal plants are found in Appalachian forests. Many of these non-timber forest products (NTFPs) have longstanding markets, some dating back to the 18th century. Today, market value for forest-based medicinal plant products exceeds one billion dollars annually in the U.S. However, aside from ginseng, prices in the traditional supply chain are often less than \$5 per dry pound. This translates to a low return on labor and limited economic incentive for sustainable cultivation or management of forest botanicals, many of which are at-risk from overharvesting and habitat loss. In 2017, Appalachian Sustainable Development (ASD) created the Appalachian Harvest (AH) Herb Hub in Duffield, VA to explore solutions to these problems. The Herb Hub's objective is to create a sustainable herbal economy in Central Appalachia where conservation is achieved through profitable cultivation in agroforestry systems. Nested within one of the oldest food hubs in the country, AH is a shared-use facility that offers training, commercial washing and drying equipment, and aggregation and marketing services to producers who grow herbs in alley cropping and forest farming systems. With commercial processing equipment, AH has helped farmers reduce their manual labor expenses by up to \$34 per dry pound. Working with buyers who are increasingly looking for high quality, sustainably harvested botanicals, AH has developed a niche market with premium prices for agroforestry producers. For example, instead of \$5 per pound for wild harvested black cohosh root, AH obtains \$45 per pound for sustainably forest farmed black cohosh. In turn, this has made sustainable cultivation of medicinal herbs profitable for agroforestry producers in Appalachia, creating financial incentive for increased adoption. ASD hopes the Herb Hub can one day become a replicable model for the agroforestry community, with expansion to other NTFPs and satellite locations.

### Farmers values for forest gardens can guide land rehabilitation

\*Kamal Melvani, Charles Darwin University, Australia

Jerry Moles, NEO SYNTHESIS RESEARCH CENTRE, Sri Lanka

Tropical forest gardens (FGs) are an ancient, tree-dominated land use. Although numbers are dwindling globally, FGs are increasing in Sri Lanka suggesting that farmers value them. Knowing why Sri Lankan farmers value FGs is vital because it can guide the establishment of tree-dominated agriculture in other tropical countries. We investigated the social, ecological, financial, food and nutrition values that Sri Lankan farmers have for FGs challenged by climate variability and animal and insect pest stressors. Using mixed methods, data were collected from 85 farming enterprises across the Intermediate zone. The Total Economic Value Framework guided investigation in short- (reference year, 2012-2013) and long-terms (beyond 2013). Forest gardens were assessed with respect to land use and crops. Forest garden land use values were compared with other On-farm land uses, Off-farm, and household components in farming enterprises, while FG (long-term) crops contrasted with very long-, short- and very short-term crops categorised by return times. Results revealed that farmers had

24 values for land and crops of which floristic diversity, income and food were highly ranked. Of all land uses, FGs demonstrated the greatest floristic diversity, area, utility benefits, income and financial efficiency. Short-term household budgets stabilised because FG profit was greater than farming enterprise profit. Current and Non-Current FG assets collectively accounted for 79% of farmers' equities, ensuring long-term financial security. While all crops provided macro and micronutrients, long- and very short-term crops were micronutrient-rich and enhanced nutritional security. Diverse crop phenologies assured households with year-round and continuous access to food. Sri Lankan farmers valued FGs because they were resilient, provided food, nutrition and financial security. This study has positive implications for land rehabilitation in the tropics because it presents a real-time, aggregated total economic value for FGs.

Farmers' Representative in this session: Zénabou Segda, Burkina Faso

Farmer's video: agroforestry in Brazil

Room 303A

## G1. Transitioning to a Viable Society

Which scaling model for sustainable agroforestry systems and landscape restoration?

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Mieke Bourne, CIFOR-ICRAF, Kenya

Ibrahim Ouattara, CIFOR-ICRAF, Burkina Faso

Jules Bayala, CIFOR-ICRAF, Burkina Faso

Agroforestry is high on the world agenda for green recovery from COVID-19, the SDGs, the AFR100 (African Forest Landscape Restoration Initiative), the GGW (the Great Green Wall), climate mitigation/adaptation and the UN decade for ecosystem restoration. This momentum translates into projects led by governments, development agencies, NGOs and CBOs to promote nature-based solutions for both the people and the environment. Participation, stakeholder engagement, and scaling modalities are vital for reaching restoration targets, improving small-holders' wellbeing while ensuring sustainability beyond project lifetime. Yet, knowledge gaps remain on how scaling models impede or enable sustainable large-scale restoration impacts. Hence, our paper to feed these gaps through the case study of Regreening Africa, a restoration project aiming at reversing degradation of 1 Million ha of agroforestry land and improving the livelihoods and resilience of 500 000 farmers across 8 African countries (Mali, Niger, Senegal, Ghana, Rwanda, Kenya, Somalia, and Ethiopia). We examined if and how approaches used in the project to engage stakeholders and scale-up restoration, enabled for social learning, a pillar of sustainability. Based on qualitative, quantitative, and GIS data, our results show that three distinct, but interconnected scaling models were used in the project: the Transfer of Technology (ToT), the Volunteer Farmer Trainers (VFT), and the CBOs based model. Each model has differentiated implications for enabling restoration targets and sustainability. The more a scaling approach provided platform for social learning among communities, the more it enabled greater and durable restoration outcome. The VFT scaling model showed higher potential for restoration and sustainability outcome. Therefore, for future restoration projects we suggest the use of the VFT scaling model.

### Agroforestry-based apiculture for livelihood resilience in rural communities: Case study of Oku in the northwest region of Cameroon

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\*Azembouh Roshinus Tsufac, Department of Forestry, Faculty of Agronomy and Agricultural Sciences, The University of Dschang, Cameroon

Apiculture is a major livelihood resilience option for rural communities in Cameroon. However, most of the bee keeping in Cameroon is still largely dependent on natural forests which makes it unsustainable owing to the large scale deforestation and degradation experienced by Cameroon's forests today. There is therefore an urgent need to adopt more sustainable apicultural practices – which is where agroforestry-based apiculture comes in. Thus, this study was carried out to examine the role played by agroforestry-based apiculture to livelihood resilience in rural Cameroon. Data was collected from 200 bee farmers (100 agroforestry practitioners and 100 non-agroforestry practitioners) in Oku sub-division, northwest region of Cameroon. It was found that, the main flowering tree/shrub species integrated by agroforestry practicing farmers in their agroforestry-based bee farms were *Nuxia congesta*, *Prunus africana*, *Podocarpus manii*, *Schefflera abyssinica*, *Zyzygium staundtii* and *Calliandra calothyrsus*. Agroforestry practicing bee farmers had more bee hives, produced more honey and made more money from the sale of honey compared to their non-agroforestry practicing counterparts who depended solely on the natural forest for bee keeping. Agroforestry practicing bee farmers equally had easy access to medicinal plants, fuelwood and wood for construction than their non-agroforestry practicing counterparts. This is attributable to the different medicinal, fuelwood and timber trees found on their bee farms. The main threat to bee keeping for both agroforestry and non-agroforestry practicing farmers was bush fire which destroyed many hives especially in the dry season. Bush fires however affected non-agroforestry practitioners more because their beehives were in the wild with little or no management while agroforestry practicing bee farmers managed their bee farms regularly and guarded against bush fires. Overall, livelihood resilience of agroforestry practicing bee farmers was far better than their non-agroforestry practicing counterparts. We therefore recommend that more bee farmers should adopt agroforestry which is a strategy to ensure the sustainability of bee farms and guarantee livelihood resilience.

### Agroforestry-Based Ecosystem Services: Reconciling Relational and Instrumental Values of Nature to Humans in Sustainable Development

\*Meine van Noordwijk, World Agroforestry (CIFOR-ICRAF), Indonesia

Background: Agroforestry as active area of multi-, inter-, and transdisciplinary research bridges artificial divides that have respectable historical roots but hinder progress toward sustainable development goals (SDGs). The ecosystem services concept has been criticized for over-emphasizing instrumental and ignoring relational values of nature to humans. Objectives: Use agroforestry to conceptually bridge three divides: (1) The segregation of “forestry trees” and “agricultural crops”, ignoring the continuity in functional properties and functions; (2) The identification of agriculture with provisioning services and the assumed monopoly of forests on other ecosystem services (including hydrology, carbon storage, biodiversity conservation) in the landscape, (3) The gaps among local knowledge of farmers/agroforesters as landscape managers, the contributions of social and ecological sciences, the path-dependency of forestry, environmental or agricultural institutions, and emerging policy responses to “issue attention cycles”. Methods: Articulate three interconnected agroforestry paradigms addressing the three challenges, with farm-scale AF1 reconnecting perennial and annual, woody and nonwoody plants across the forest-agriculture divide to markets for inputs and outputs, landscape-level

AF2 addressing multifunctionality in heterogeneous social-ecological systems and the opportunity of “integrated” solutions, and policy-level AF3 taking up a holistic SDG perspective. Results: Increasing reference to agroforestry in high-level policy documents emphasizes SDG relevance of integrated approaches to land use, but does not by itself overcome existing barriers. Discussion on rebalancing instrumental and relational values for various policy contexts and audiences made some progress. The Glasgow forest declaration uses forest and sustainable land use as equivalent, leaving room for agroforestry-friendly interpretation and operationalization. The IPBES Values Assessment will be discussed and hopefully approved the week before the 5th World Agroforestry Congress, allowing the current embargo on spreading its conclusions to be lifted. Discussion and conclusion: Overcoming resistance to an ever-changing vocabulary, agroforestry can connect various global challenges of today, with relationally valued trees rooted on farms.

### Sustainable livelihoods approach to develop indicators of livelihood resilience in agroforestry systems

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The sustainable livelihoods approach states that livelihoods should be considered in terms of people’s access to capital assets (financial, physical, natural, human, and social), the ways in which people combine these capital assets to create livelihoods, and how they are able to enlarge their asset base through interactions with other actors and institutions, to what extent the intensity of agroforestry systems contribute to these capitals is still unclear. In this paper, we calculate each of the capital assets as an approximation to measure resilience for different levels of intensity in agroforestry systems in Guatemala and Costa Rica. A survey was applied from November 2019 to February 2020 collecting 20 variables to measure all capitals. We create a simple additive, or composite asset index for each household as outlined in Campbell et al. (2001) and Erenstein et al. (2007). Preliminary results show that Costa Rican farmers are more resilient than Guatemalan farmers, particularly due to higher levels of human and financial capitals. Regarding the intensity of agroforestry, it is observed that farmers with high production and medium shade in their farms, have higher physical capital and lower levels of natural capital. For farmers with very low production and low shade we observed similar results, low levels of natural capital but higher levels of social capital. Regarding resilience, preliminary results show that farmers with medium shade and medium production show the higher levels of resilience, therefore, balancing the interaction between the five capitals allows farmers to be recover more easily when facing climate shocks.

Farmers’ Representative in this session: Denise Bittencourt Amador, Brazil

Room 301B

## H4. Transitioning to a Viable Development

### Evaluation of agroforestry benefits in northwest Vietnam using a multidisciplinary approach

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\*Van Hung Do, World Agroforestry (ICRAF) Vietnam, Vietnam

Nguyen La, World Agroforestry (ICRAF), Vietnam

The northwest region of Vietnam, conventional agriculture is dominated by sole crop cultivation on steep slopes, including extensive tillage and crop residue burning. This is accompanied by extensive degradation of land and other natural resources and un-sustainable production systems. Agroforestry has since many years been recognized as a more sustainable way to provide food, other products and services. In order to assist farmers to shift from unsustainable practice of sole annual crops to agroforestry, we evaluated the economic and environmental of six agroforestry options including fruit trees, timber trees and short-term crops. Sole-cropped of annual crops were used as controls. Social benefits of agroforestry practices were investigated through household interview with farmers who participated in implementing agroforestry options. The results showed that six evaluated agroforestry options provided earlier and more diverse products than sole-cropped systems. Furthermore, from years two and year three, these agroforestry options provided better profitability than corresponding sole-cropped systems although the initial investment costs of six agroforestry options were higher. When we compared to a sole-cropped maize option, agroforestry options serve a substantial role in preventing soil loss due to soil erosion. The local interview revealed that introducing agroforestry options helped increase farmer awareness and capacity in adopting tree-crop intercropping and soil conservation techniques. Social benefits that farmers have gained included improved teamwork, enhanced connection with other farmers, improved ability to talk in public, decision making and their confidence to implement agroforestry. Local farmers confirmed that scaling up agroforestry options in the region required financial support to tackle the investment, as well as an improved market-value chain, particularly in terms of market stability. Agroforestry expansion needs to be flexibly integrated into agricultural and forestry land use plans, as well as agricultural support programs in each location.

### Proposal of indicators for the evaluation of silvopastoral practices and their contribution to the sustainability of native forest in South America

\*Francis Dube, Universidad de Concepción, Chile

María Gabriela Medina Rivero, Universidad de Concepción, Chile

This study builds on research carried out with the aim of generating an appropriate set of economic, environmental and social indicators that help evaluating sustainability trends, associated risks and decision-making in native forest ecosystems in silvopastoral conditions. A native forest of old oak trees, under silvopastoral management in Yungay commune, Chile, serves as case study. The methodology used was methodological triangulation (bibliography-experts-community). In total, 233 indicators were considered and from the simultaneous comparison of the data, 22 emerged as the most relevant to assess sustainability. Additional 26 indicators are classified as complementary to the scope of evaluation. The combination of methods (review, survey, participatory methodology, multivariate analysis) not only contributed to the simplification of data but also bolstered the validity of the results and mitigate the bias in the methodological framework. The group of potential indicators generated are considered adequate for evaluation and respond to the objectives of each of the sustainability dimensions. To improve indicator selection, it is suggested to analyze their usefulness, degree of difficulty,

and relevance of the data they will provide to make the necessary adjustments and synthesize objective and clear values that provide reliable data toward sustainability and the potential of silvopastoralism.

### Transformation of coffee-growing landscapes across Latin America

**\*Vivian Valencia, Wageningen University and Research, Netherlands**

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Alyssa Pritts, Wageningen University and Research, Netherlands

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Jansen Kees, Wageningen University and Research, Netherlands

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Jacques Avelino, CIRAD, Costa Rica

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Christian Bunn, CIAT, Colombia

Javier Hoyos, TECNICAFE, Colombia

Carlos Isaza, Solidaridad, Colombia

Juana Munoz, Cornell University, United States

Carlos Perez, Solidaridad, Panama

Eric Rahn, CIAT, Colombia

Valentina Robiglio, ICRAF, Peru

Eduardo Somarriba, CATIE, Costa Rica

**Background:** In Latin America, the cultivation of Arabica coffee (*Coffea arabica*) plays a critical role in rural livelihoods, biodiversity conservation, and sustainable development. Over the last 20 years, coffee farms and landscapes across the region have undergone rapid and profound biophysical changes in response to low coffee prices, changing climatic conditions, severe plant pathogen outbreaks, and other drivers. Although these biophysical transformations are pervasive and affect millions of rural livelihoods, there is limited information on the types, location, and extent of landscape changes and their socioeconomic and ecological consequences. **Objectives:** We review the state of knowledge on the ongoing biophysical changes in coffee-growing regions, explore the potential socioeconomic and ecological impacts of these changes, and highlight key research gaps. **Methods:** This review integrates expert knowledge harvested in a 4-day international workshop at International Center for Tropical Agriculture (CIAT) and a literature review. **Results:** We identify seven major land-use trends which are affecting the sustainability of coffee-growing regions across Latin America in different ways: (1) the widespread shift to disease-resistant cultivars, (2) the conventional intensification of coffee management with greater planting densities, greater use of agrochemicals and less shade, (3) the conversion of coffee to other agricultural land uses, (4) the introduction of Robusta coffee (*Coffea canephora*) into areas not previously cultivated with coffee, (5) the expansion of coffee into forested areas, (6) the urbanization of coffee landscapes, and (7) the increase in the area of coffee produced under voluntary sustainability standards. **Discussion:** Our review highlights the incomplete and scattered information on the drivers, patterns, and outcomes of biophysical changes in coffee landscapes, and lays out a detailed research agenda to address these research gaps and elucidate the effects of different landscape trajectories on rural livelihoods, biodiversity conservation, and other aspects of sustainable development. **Conclusion:** A better understanding of the drivers, patterns, and consequences of changes in coffee landscapes is vital for informing the design of policies, programs, and incentives for sustainable coffee production.



## Ex-post assessment of the stated behavioural intentions to plant trees on farmlands in Mokhada, Maharashtra, India

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Neal Hockley, Bangor University, United Kingdom

This study follows up on research by Brockington et al. presented at WCA4 in Montpellier in 2019 on adoption of 'wadi' (orchard) agroforestry promoted by BAIF by smallholder tribal farmers. In 2016, the Theory of Planned Behaviour (TPB) was used to assess the likelihood of smallholder farmers planting at least 20 more trees on their farms over the next two years. That research demonstrated that including intrinsic variables including attitude towards agroforestry by the farmer, opinions of others and the farmer's ability to overcome perceived difficulties, alongside extrinsic variables such as previous experience of agroforestry, distance to water, area of farmland and availability of labour greatly improved regression models of those farmers' stated behavioural intentions to plant trees. An important test of the usefulness of the TPB would be to determine whether farmers carried their stated intentions to plant more trees. The follow up survey in 2021 (delayed by almost two years due to the Covid-19 pandemic, and eventually had to be conducted by telephone) located 76% of the previous 143 respondents. Stated behavioural intention was a strong predictor of subsequent tree planting behaviour (Table), farmers planting an average of 124 trees of a wide range of fruit and timber species per farm, almost all within three years. The other significant predictor of tree planting was availability of agricultural labour, but not wealth class, size of farm nor previous experience of agroforestry. Some farmers with no previous experience were enthusiastic planters of trees. The results validated the hypothesis that the TPB can predict future likelihood of tree planting behaviour which is of great use for agroforestry extension. Furthermore, it was shown that the BAIF 'wadi' agroforestry model was highly acceptable even to poor farmers in a degraded hilly landscape, and was diffusing among previously non-adopting farmers.

## Economic contribution of shea butter value chain for households in Cameroon

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Stepha McMullin, World Agroforestry (ICRAF), Kenya

Vladimir Verner, Czech University of Life Sciences, Prague, Czech Republic

Shea tree (*Vitellaria paradoxa* C. F. Gaertn.) is deemed the second important oil crop across the Sudano-Sahelian region of Africa, after palm oil. The collection and sale of shea nuts and their processing, as well as the sale of shea butter is a source of income for many rural communities in Cameroon. However, very little is known about the importance of income from the shea value chain in Northern Cameroon. Our explorative study aimed to investigate the share of shea butter income in the total household; identify household characteristics that determine the dependence of households on shea income; determine what income from the shea value chain are used for household expenditures. Data from 384 shea butter producers and non-producers were collected in face-to-face interviews through a semi-structured questionnaire in 2021. OLS regression was used to determine the household characteristics affecting the share of total household income from shea. Our results show that the average total annual household income is 307,071 XAF (529.68 USD) and 335,141 XAF (578.10 USD), respectively, for shea producers and non-producers' households. Shea butter income accounts for 25.46% of the total household income and 34.44% of the total cash income of the household. Our results found a significant correlation between dependency and the number of days spent collecting shea nuts. Income earned from Shea butter allows the

poorest households to buy essential things like clothes and shoes, food and pay for healthcare, while the richer households use the shea income to make productive investments such as purchasing land and farm inputs. With financial and technical support, Shea producers can increase their productivity and production. The improved processing technologies can be a pathway to raise the household income of local communities and diversify their livelihood. Keywords: Indigenous tree species, poverty alleviation, household economy, dependency, livelihoods, Cameroon.

Farmers' Representative in this session: Gabriela Delgado, Guatemala

Room 203

#### L4. Which Agroforestry for Commercial Perennial Crops and Trees?

The optimal design of coffee and cocoa agroforestry systems

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Moisés Solano, University of Costa Rica, Costa Rica

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The use of shade trees in cocoa and coffee cultivation is a management practice prevalent in Latin America but less so in both Africa and Asia, although this is changing. Cocoa and coffee agroforestry systems are classified in at least six broad typologies that reflect the management objectives of the farmer. However, most cocoa and coffee agroforestry systems on smallholder farms are suboptimal in design and management. The reasons for this are poorly understood. Designing optimal shade canopies in coffee/cocoa agroforestry systems is a complex process. Farmers must select the right species, regulate tree population densities, choose the best planting arrangements, and management practices to optimally “fill up” the volume occupied by the shade canopy (a volume, a 3-D object). Optimum agroforestry design requires the analysis of interactions and trade-offs between the various components of the agroforestry system and the objectives of the farmer (Figure 1), which in most instances involve tradeoffs between competing goals such as improving their livelihoods and providing other ecosystem services. In this presentation we describe the development of a mathematical optimization approach to shade canopy design based on the manipulation of a set of differential equations representing the interactions between components and goals in the agroforestry system. Mathematical functions describing the interactions (arrows) between the different components (words) of the agroforestry system are determined based on published scientific knowledge combined with expert knowledge acquired using various techniques. The analysis of shade levels and spatial and temporal patterns are assessed with the software ShadeMotion ([www.shademotion.net](http://www.shademotion.net)), Preliminary estimations are presented for the traditional cocoa – *Cordia alliodora* system prevalent in Central America.

### Long-term effects of shade and input levels on coffee yields in the Pacific region of Nicaragua

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Elvin Navarrete, CATIE, Nicaragua

Ledis Navarrete, CATIE, Nicaragua

The suitability and profitability of coffee cultivation in Central America are at risk due to pest and disease outbreaks, price fluctuations and climate change. Proper shading is claimed to be one of the most promising practices to seek sustainability and better adapt coffee cultivation to climate change in marginal areas. This study recorded and compared coffee cherry yields over a ten-year period from shaded coffee (N-fixing-trees and timber trees) agroforestry systems under different management regimes (conventional vs. organic) in a suboptimal site for cultivating coffee. We found significant differences in production between conventional inputs management regime vs. the combination of organic inputs regime and shade types in some years of the evaluation period. Full-sun cultivation under intensive management was the most productive system for coffee yields, followed by shaded systems under timber trees. Interestingly, and regardless of management systems (intensive conventional or intensive organic) the worst combinations in terms of coffee yield were shaded systems under leguminous species (*Inga laurina* (Sw.) Willd. + *Simarouba glauca* DC.). Across all experimental plots, the timber species *Simarouba glauca* and *Tabebuia rosea* (Bertol.) DC. grew well, reaching a mean annual increment in diameter of 2.5-3.3 cm/year (age 12 years). Average gross revenues were higher in full-sun and timber-shaded agroforestry systems. Overall, intensive management regimes were the most expensive cultivation system to run but also the best in terms of coffee yield performance. This study showed that intensive organic production was equally productive as conventional production regimes.

### Assessing tree growth rates and cocoa yields over 20 years in Honduras

\*Luis Orozco Aguilar, Lutheran World Relief, Costa Rica

Oscar Ramirez Argueta, FHIA-Honduras, Honduras

Javier Diaz Matute, FHIA, Honduras

Fernando Casanoves, CATIE, Costa Rica

Aroldo Dubon Dubon, FHIA-Honduras, Honduras

Cacao in Honduras is cultivated under traditional shade tree species (*Inga* sp., *Erythrina* sp., *Gliricidia* sp.), fruit and timber species selected and managed from natural regeneration. Typically, these shaded plantations are poorly managed resulting in high tree density and heavy shading, thus affecting the agronomic and yield performance overtime. We assessed 36 cocoa plots made up between 15-36 useful timber shade trees with varying spacing 6 × 9, 9 × 9, 8 × 10 and 10 × 12 m. Initially, each plot consists of three shade components plus cacao. Plantain (*Musa* sp.) and madreño (*Gliricidia sepium*) were used as temporary shade and timber species, with good market potential, were selected for permanent shade. Dasometric data was retrieved to assess growth rates of timber species and explore the effects of shade cover on cocoa yields and incidence of diseases. Specifically, we: a) calculated growth rates and build curves for diameter (DBH), total height (Ht) and commercial

volume (Vc) and compared the growing performance with ANOVA and DGC tests; b) run a correlation analysis between tree cover, basal area of timber trees, cocoa yields, and the incidence of monilia and black pod. Statistical differences were found in terms of growth rates among timber species evaluated. Mean annual growth rates were 1 m in Ht, 2,25 cm in DBH and gained 4,2 m<sup>3</sup>/ha/year of commercial timber. Cocoa yields ranged between 950-1365 kg/ha/year and were negatively affected by both increased shade cover and timber basal. Cocoa yields were reduced up to 25% when shade cover and tree basal area were over 35% and 9 m<sup>2</sup>, respectively. Regardless of timber tree species, no significant effect of shade cover was found on the incidence of both monilia and black pod. Timber-based cocoa plantations are a promising alternative for farm diversification in the Atlantic region of Honduras.

### Tree planting pattern and plant diversity are major determinants of productivity in mango-based orchards in Senegal

Julien Sarron, CIRAD, France

\*Eric Malezieux, CIRAD, France

Emile Faye, CIRAD, France

In West Africa, mango is a major fruit tree that contributes significantly to food security and economy of smallholders. Mango tree is cultivated in different cropping systems that vary from diversified, which include various perennial and annual species, to large commercial-based monospecific orchards. These systems may recover different levels of productivity whose determinants are unknown. In this study we determine how orchard structure, including plant diversity and planting pattern (planting density and spatial organization), affect mango productivity. Thirty orchards representing the three types of mango-based cropping systems (extensive, diversified, and intensive) in Senegal were mapped using unmanned aerial vehicle (UAV). In 2017 and 2018, individual mango tree cultivar and dimension (crown area) were extracted from UAV models and combined with a load index to estimate variables of mango productivity: orchard yield (t.ha<sup>-1</sup>), tree mean yield (kg.tree<sup>-1</sup>) and yield efficiency (kg.m<sup>-2</sup> of mango canopy). Plant diversity and planting pattern were characterized using 14 different indices. Results show that orchard productivity highly depends on the cropping system: orchard yield and yield efficiency are higher in intensive orchards than in extensive or diversified orchards. However, diversified orchards reached higher mean tree yield and intermediate yield efficiency. Analysis of correlations between plant diversity and planting pattern variables made possible to select four variables (i.e., mango planting density, number of species, citrus percentage of land, and Shannon's evenness index) and to explore their effect on each productivity variable. Orchard mango yield was positively affected by mango density and species diversity (Shannon index) ( $R^2 = 0.63$ ). Finally, yield efficiency was positively impacted by mango density but negatively impacted by species diversity ( $R^2 = 0.46$ ). These results highlighted the effect of plant diversity and planting pattern as major determinants of mango productivity. However the overall productivity of the orchard, including other species will have to be considered in further studies.

### Comparison of the contribution of a participatory approach and a mathematical modelling in the design of complex agroforestry systems

\*Martin Notaro, Cirad, Ivory Coast

Olivier Deheuvels, CIRAD, Dominican Republic

Christian Gary, INRAE, France

Redesigning our agricultural systems has become a priority today in order to limit the negative impacts on the environment and global health caused by our farming systems. Two main types of approach to the design of innovative cropping systems exist: the top-down type, a linear approach where research produces knowledge that is disseminated by advisory agencies to farmers, and the bottom-up type, a participatory approach that includes a set of relevant actors to produce innovations. We tested these two approaches for the design of cocoa-based agroforestry systems in the Dominican Republic. On the one hand, agronomic monitoring of 34 agroforestry plots allowed us to produce different prototypes for optimizing the functioning of these systems using different algorithms. On the other hand, an original participatory design process was conducted to develop four prototypes of innovative cocoa agroforestry systems. The economic and environmental sustainability, through the biodiversity grown within the prototypes from these two types of approaches, are compared. The mathematical modelling approach resulted in prototypes that are less diverse than those from the participatory approach, with a crop biodiversity from 2 to 4 species and from 4 to 7 species respectively. From an economic point of view, the results are also weaker, with a turnover of between US\$ 2500 and US\$ 3500 ha<sup>-1</sup> yr<sup>-1</sup> for the modeling approach compared to US\$ 6683 to US\$ 8670 ha<sup>-1</sup> yr<sup>-1</sup> for the participatory approach. These systems have real potential for improvement because the complexity of interactions between different crop species, and in particular of facilitation processes, is still poorly explored. The strengths and weaknesses of the two methods are discussed and clearly indicate that hybrid approaches, giving a prominent place to both rural and research actors, would provide more disruptive and sustainable solutions.

Room 204A

## M2. Which Agroforestry for Integrating Livestock to Trees and Crops?

Rotational cattle grazing, canopy thinning, and vegetation management shifts plant community and soil properties in oak woodlands in the US Midwest

\*Keeffe Keeley, Savanna Institute, United States

Stephen J. Ventura, University of Wisconsin-Madison, United States

Overgrazing by domestic livestock has historically degraded woodlands, but herbivory more generally represents a source of disturbance important to ecosystem structure and function. Oak ecosystems in the Driftless Area, and the eastern US more broadly, lack appropriate disturbance and are undergoing successional mesophication. Silvopasture potentially offers a land management strategy to mitigate the degrading effects of overgrazing and to restore successional heterogeneity to the landscape. In this study, we evaluated impacts of prescribed grazing and vegetation management on plants and soils in oak-dominant mixed species woodlands. Specifically, we assessed the influence of cattle, thinning canopies, and planting forages on shrub cover, floristic diversity, forage nutritive quality, soil cover, soil fertility, and soil microbial community structure. This was done on farms with already established rotational grazing management systems. Grazing reduced shrub cover where initial thinning occurred and more so with native than introduced shrub species. Planting agricultural forages reduced floristic diversity but did not increase forage quality. Bare soil exposure and soil compaction was greater in grazed areas, but canopy thinning appeared to moderate the former. No effects were detected on soil moisture or macronutrients. Impacts on soil microbial community composition were mixed. In grazed areas soil actinomycetes were more abundant, soil fungi were less abundant, and fungi to bacteria ratio was marginally greater in areas without any grazing or vegetation management. Arbuscular mycorrhizal fungi were less abundant in grazed areas when canopy and shrubs were thinned. Our

findings suggest that management of existing woodland grazing can be improved by prescribed canopy thinning and targeted management of the shrub layer.

### Grazing management reduced cattle growth but limited pasture depletion in a Mediterranean agrosilvopastoral system

Alice Ripamonti, University of Pisa, Italy

Giovanni Pecchioni, Institute of Life Sciences, Sant'Anna School of Advanced Study, Italy

Francesco Annecchini, Institute of Life Sciences, Sant'Anna School of Advanced Study, Italy

Laura Casarosa, University of Pisa, Italy

Alessio Del Tongo, Tenuta di Paganico Soc. Agr. SpA, Italy

Jacopo Goracci, Tenuta di Paganico Soc. Agr. SpA, Italy

Marcello Mele, University of Pisa, Italy

\*Alberto Mantino, Institute of Life Sciences, Sant'Anna School of Advanced Study, Italy

Two groups of growing steers and heifers of Maremmana cattle breed (average age and weight of  $321 \pm 56$  d and  $287 \pm 57$  kg) were managed under two different treatments (silvopasture vs. open pasture) to evaluate if grazing management influences cattle growth. The trial was carried out in a Mediterranean agrosilvopastoral system, located in central Italy, during spring 2021. To perform rotational grazing 3.69 ha of temporary grassland were divided into six paddocks, three for each treatment. Cattle grazed for one weeklong on a single paddock and then they were moved to the next one. Group maintained on silvopasture system was allowed to access to 3.31 ha of Turkey-oak forest. Average daily gain was calculated by weight cattle at the beginning (25/03), in the middle (15/04) and at the end of the trial (06/05). Statistical analysis of animal weight was performed with R software using a linear mixed-effect model. A significant interaction was found between system and time, indeed the average daily gain of animals grown in the open pasture was 1.20 kg/day, while that of cattle grown in silvopastoral system was 1.02 kg/day. Despite the rate of growth falling into the expected range for the Maremmana breed, the average daily gain of cattle on silvopastoral system was significantly lower probably due to higher amount of surface available that, in turn, affected the energy requirements of animals. However, allowing cattle to graze in the forest reduced pasture depletion because of the lower stocking rate and grazing pressure (Fig. 1). Indeed, looking at the aerial picture taken last day of the trial, the paddocks grazed by open pasture group were more depleted compared to the paddocks grazed by silvopastoral group.

### AgroforesTrue: improving food self-sufficiency with fodder trees for pig farms

\*Fabien Liagre, AGROOF, France

Alibert Laurent, IFIP, France

Agroforestry systems for pig farms represent 1% of pig farms in France. But under social and policy pressure, the obligation of free-range becomes more and more present in certified productions. But a single pasture without tree poses different questions in terms of resilience: lack of animal protection, problem of soil erosion, lack of intrinsic forage resources... AgroforesTrue has been exploring the potential of trees since 2019 in order to improve the qualities of these rangelands with improvements aimed at several objectives, in particular food self-sufficiency and animal welfare. The first actions carried out were to identify traditional rangelands, in France and abroad, to harvest samples of seeds and fruits from different trees and to set up the first pilot sites with varietal and protection tests (on young plantation or existing old trees).

Among the species whose fruits have been analysed, we analysed a large range of oaks and chestnut trees, known for their traditional uses. But the originality of the project was also to analyse the little-known wild fruit trees (*Arbustus unedo*, *Sorbus domestica*, *Pyrus pyraeaster* and *Malus sylvestris*, *Ficus carica*...). A database was created to integrate the food value and productivity of 30 trees species. This work will support farmers in their planting project in order to optimize the feed rations for their animals, thus aiming at the goal of food autonomy and well-being. The first pilot sites were thus planted in order to integrate this new dimension for pig systems. As a result of this fruit analysis work, the most promising individuals in terms of quality and yield will be selected to begin the nursery production in 2022. The objective is to initiate the production of fodder trees mainly dedicated to pig farms in a near future, adapted to the climatic changes.

### Agroforestry systems including livestock activities in Guadeloupe

\*Gisele Alexandre, INRAE -URZ, France

Agathe Cheval, INRAE -URZ, France

Jean-Louis Diman, INRAE -Peyi, France

Arsene Vinglassalon, Syaprovag, France

The forest land reserve in Guadeloupe is 71,500 ha, representing 44% of the total land area. Forests have traditionally contributed to the economic development of the territory until the post-war bipolarization of the Guadeloupean "sugar cane/banana. The value-enhancement of Guadeloupe's private forests (48% of the total) is a major challenge for the territory in terms of agroecological transition. In many Latin-America regions, agroforestry systems (AFS) include a significant proportion of livestock but very few do in Guadeloupe (F.W.I.). A great diversity of forests can be observed according to the rainfall regime and the altitude, with a gradient of xerophilic, mesophilic and hygrophilic forests. In the driest zone the dominant type being semi-deciduous forest. In this study, AFS including livestock activities were classified through semi-open interviews (n = 50) based on two dimensions, the agricultural region and the farmer's main production strategy. On average, AFS are family farming systems (more than 30%) and the percentage of farmers with multi-activities is high (77%). At first glance, beekeeping is the most widespread or most recognized activity in wooded areas. But there is evidence for the presence of other animals and breeding activities. Mixed tree-crop-livestock systems are very frequent, with 1/3rd of the sub-units devoted to animal husbandry. Farmers preferably raise small ruminants, backyard animals and large herbivores (20 to 25% of answers each), plus to a lesser extent, raise pigs and keep bees (12% each). Mixed animal units exist (50%) with between two and six species. More than 80% of farmers use their farm resources (pastures, natural fodder trees or crop by-products) to feed their animals. Even though self-consumption remains widespread (50% of responses), 80% of the farmers want to give a more economic orientation to their activities. The other responses (16%) concerned socio-cultural functions. This mixed system is a prerequisite for agroecological transition.

### Interaction of humans, animals, trees and crops: the case of the Tenuta di Paganico farm.

\*Jacopo Goracci, Farmers' Representative, Italy.



6:30 pm, Château Frontenac

## Banquet Reception

Join us for an evening of great gourmet cuisine and internationally acclaimed local music at the iconic Château Frontenac! On the program: a welcome cocktail, a multi-course menu with local flavour from a renowned chef and lively Quebec trad music to end the banquet in style! Blending the very best of Quebec's heritage with the latest design trends, featuring re-invented cutting-edge local cuisine, the chef will create a unique and memorable boreal culinary discovery that is second to none.

The group of five musicians are amongst the leading figures in Quebec's trad scene. Some of them are responsible for kickstarting Quebec's folk music revival. Drawing inspiration from New-France and Irish music, with melodious vocals, inventive guitar, violin, and percussion, they also bring a wonderful sense of humour that makes them irresistible.



At the end of the Plenary Sessions

Dance

## *Transitioning to a Viable World*

by Morgane Litzler

@morganelitzler

How to illustrate an agroforestry congress through dance? When reading the themes of the plenary sessions, it was nature that seemed to me like a common thread: the countryside, the cultivated fields, the forest, the trees, the gardens but also, by contrast, the city and the rarity of greenery. I had to put these notions into motions. What could be more inspiring than nature? My imagination hastened to set my body in motion: ample and constricted gestures, wide and jerky movements, slow and fast.

In each of the chosen spaces, I wished to integrate myself as well as possible into the environment. Progressively, notions became associated with movements. Nature really inspired me, it worked in me as if it dictated postures, movements, rhythms, ...

So, little by little, inspired by nature, I created my choreography.

Morgane Litzler started dancing in 2007, when she was 3 years old, and it quickly became a passion. She took the dance option in high school and even did her last year of high school online, to have more time to dance. She learnt many types of dance at the *Centre Cynthia Joffre in Rixheim* (France): contemporary dance, classical ballet, jazz, street'jazz, dancehall and afro dance. She was also a member of the *Compagnie Pourquoi Pas* from 2019 to 2021. She took part in festivals and workshops such as *MoveMentors* (SEAD, Austria) and professional training with Edouard Hue of the *Beaver Dam Cie* (Geneva, Switzerland). These experiences help her discover more types of dance: gaga, flow acrobatics, flying low, improvisation, modern

and urban dances. She attended the *Accademia Susanna Beltrami* in Milano and will start her bachelor in Dance at the *Pera Dance School* of Girne American University (Cyprus) next year.



Wednesday, July 20, 2022

8:30 am

## Parallel Sessions

Room 200A/B

### Workshop: Farmers' Voices 1

These workshops will be accessible to all delegates and will also be offered free of charge online. They are aimed primarily at people practicing agroforestry around the world and at associations supporting them. Designed and developed in response to questions and concerns shared during satellite events organized on the sidelines of the congress, they aim to provide participants with a space for learning, building knowledge and discussing common agroforestry concerns.

with: Kumar Neeraj (India), Erminda Barosso Pacheco & Eulogia Isabel Cordoba (ColombieJustice Zvaita (Zimbabwe), ), Jacopo Goracci (Italy), Rafael Pompa (UK), Frédérique Lavallée (Canada), Jog Raj Giri (Nepal), Yvan Perreault (Canada) and more.

Languages: English, French & Spanish

Room 204B

### Workshop: The role of trees in food systems

This workshop will take the form of a panel where young researchers will have the chance to discuss the role and place of trees in food systems. Accompanied by Danielle Nierenberg, president of Food Tank, the panellists will discuss the issues surrounding agroforestry and the impacts that the adoption of certain agroforestry interventions can have on the various links in the food chain.

with Astrid Galvez Ciani, Pur Projet ; Genna Tesdall, Young Professionals for Agricultural Development ; Mark Kebo Akparibo, Tele-Bele, Ghana ; Emilie Houde-Tremblay, Université Laval, Québec & Florence Reed, Sustainable Harvest, USA.

Language: English

Room 202

## A2. Transitioning to Healthy Soils

Soil health in temperate agroforestry systems: What effects of tree rows and tree species?

\*Romane Mettauer, INRAE, AGROCAMPUS OUEST, France

Alexis Thoumazeau, CIRAD, France

Samuel Le Gall, IBG-3 Agrosphere, Forschungszentrum Jülich, France

Alexis Soiron, INRAE, France

Nancy Rakotondrazafy, IRD, France

Annette Bérard, INRAE, France

Alain Brauman, IRD, France

Delphine Mezière, INRAE, France

Alley cropping agroforestry —whereby tree rows are integrated in crop plots— is considered as a lever to intensify ecosystems services within temperate cropping systems. Despite this, its potential benefit for enhancing soil's functions is rarely studied. Here, we investigate soil health heterogeneity in temperate alley cropping agroforestry systems according to two factors: the position relative to the tree row, and tree species with contrasted functional traits that might influence local microclimate. The study was performed in one of the few mature and species-diverse agroforestry systems in Europe (Domaine de Restinclières, France; 25-year-old trees). Soil health was assessed using two integrative methods (Biofunctool®, MicroRespTM) in three positions in the field (in the middle of the tree row; at 0.5 m from the tree row in the crop alley; at 6.5m from the tree row in the middle of the crop alley), and for three tree species. The position relative to the tree row explained most of the soil health differences. The highest soil health scores were found in the tree row, whilst both positions in the crop alley had similar soil health scores. Tree species impacted soil carbon dynamics and microbial catabolic profiles only. This study confirmed the clear effect of the position relative to the trees observed in other recent studies while it highlighted the role of trees in helping to engineer ecosystems. Higher impact is even expected when considering other specific species as nitrogen fixing trees. Thus, this study underlines the importance of considering spatial organization and tree species choice to optimize soil ecosystem services within temperate agroforestry plots.

Soil quality changes within a *Nothofagus* forest under silvopastoral management in the Andes Mountains, southern Chile

\*Francis Dube, Universidad de Concepción, Chile

Pablo Neira, Universidad de Concepción, Chile

Neal Stolpe, Universidad de Concepción, Chile

In Chile, 49.1% of the national territory is affected by soil degradation (including erosion and loss of soil organic matter), whereby of the 51.7 Mha that have been historically associated with agricultural-livestock and forestry activities, only 35.5 Mha are being used at the present. Consequently, soil degradation has resulted in the release of about 11.8 Gg yr of carbon (C) equivalent (CO) to the atmosphere. Silvopastoral systems (SPS), however, can increase soil organic C (SOC) through sequestration (C→SOC), improve ecosystem services, and have been internationally recommended for sustainable land use. Therefore, it was proposed to determine the effects of SPS on soils, over five years, in degraded sites that were located in the Ranchillo Alto (SPS-RA) (37°04'52" S, 71°39'14" W), Ñuble region. The sites were rated according to previous canopy disturbance levels (+) as follows: open (O)+++, semi open (SO)++, and semi closed (SC)+. The analysis was performed on

different physical and chemical soil properties (0–5 and 5–20 cm depths), that were expressed as soil indicators (S) for chemical and physical properties, which were used to calculate a soil quality (SQ) index (SQI). The results indicated overall SQI values of 37.6 (SC) > 29.8 (O) > 28.8 (SO), but there were no significant variations ( $p < 0.05$ ) in physical SQ, whereas chemical SQ varied in all conditions, mostly at 0–5 cm in O and SO. Increases of SOC were also observed (2015–2018 period) of 22.5, 14.5, and 4.8 Mg ha for SO, O, and SC, respectively, showing that SPS promote the reclamation of Ranchillo Alto volcanic soils.

### Alley Cropping systems impact soil quality and related functions

Esther Guillot, INRAE, France

Philippe Hinsinger, INRAE, France

Cornelia Rumpel, CNRS, France

\*Isabelle Bertrand, INRAE, France

Agroforestry systems are of growing interest due to their capacities to provide a range of ecosystem services. However, soil quality based on multicriteria approach assessment has, to our knowledge, never been comprehensively assessed in temperate agroforestry systems, especially considering the spatial heterogeneity created by those systems. Our aims were to evaluate if alley-cropping agroforestry system can lead to spatial gradients of soil quality from the tree row to the middle of the cropped interrow and if soil quality is different between an agroforestry and a conventional plot. An alley cropping site of 21 years old located in the South of France was sampled in 7 contiguous areas along a transect from the middle of the interrow on each side of the tree row in an alley-cropping agroforestry plot and in an adjacent conventional plot. We measured physical, chemical and biological indicators such as soil texture, SOC, N and P contents, microbial biomass, activity and microbial community structure. Those indicators were integrated in soil quality indices (SQI). Within the agroforestry plot the soil quality index was significantly improved until 2 m from the tree row in the cropped interrow (Fig. 1). The SQI weighted average of the agroforestry plot was significantly higher than the one calculated for the conventional plot. The higher input of organic litters and changes in microorganism's community structure in the agroforestry plot compared to the conventional plot are likely at the origin of this soil quality improvement.

### Riparian land-use alters microbial networks and key taxa associated with nitrous oxide and carbon dioxide emissions

\*Tolulope Mafa-Attoye, University of Guelph, Canada

Megan Baskerville, School of Environment, Resources, and Sustainability, University of Waterloo, Canada

Dasiel Obregón Alvarez, University of Guelph, Canada

Eduardo Mitter, University of Guelph, Canada

Maren Oelbermann, University of Waterloo, Canada

Naresh Thevathasan, University of Guelph, Canada

Kari Dunfield, University of Guelph, Canada

Riparian buffer systems (RBS), due to their unique location between agricultural lands and aquatic ecosystems, have altered soil physicochemical properties increasing their potential for greenhouse gas (GHG) emissions. However, little is known about the soil microbiota, including microbial communities involved in the transformation of soil carbon and nitrogen within RBS. In four contrasting RBS namely undisturbed natural forest (FOR1), coniferous forest (FOR2), rehabilitated agroforest

(AGROFOR), grass buffer (GRASS), and an agricultural land (AGR), we analyzed the relationship between active soil microbial community structure, soil parameters and GHG. Soil samples (0-10 cm) were collected concurrently with measurements of nitrous oxide (N<sub>2</sub>O) and carbon dioxide (CO<sub>2</sub>) emissions every 2 weeks from March-November 2018. RNA extracted from soil sampled on July 4 and August 15 was used for cDNA amplicon sequencing, and the data was explored for microbial diversity, community composition, and microbe-microbe interactions. There was no significant difference in N<sub>2</sub>O emission across the RBS and AGR, however, CO<sub>2</sub> was significantly higher in GRASS compared to the other sites. Differences in nitrogen-cycling gene expression were observed, and the potential activity of nitrogen-cycling communities was higher in FOR1 compared to other sites. Bacteria diversity was lower in FOR2 and taxonomic differences were observed between sites. Network analysis showed differences in the co-occurrence patterns of microbial communities across sites. Unique associations between microbial taxa, GHG, and soil parameters such as soil organic carbon that potentially influenced microbial community structure were identified. Various active microbial taxa such as Burkholderiaceae and Candidatus-udaeobacter were associated with N<sub>2</sub>O and CO<sub>2</sub> emissions across the sites. Overall, our results indicate differences in soil microbial communities across the different RBS as influenced by soil factors and GHG. The identified microbial taxa could potentially influence GHG dynamics and contribute to mitigation strategies in RBS.

### Agroforestry transitions to healthy soils: Linking trees, soil biota and ecosystem services

\*Edmundo Barrios, Food and Agriculture Organization of the United Nations (FAO), Italy

Soil health is a measure of the state of natural capital that reflects the capacity of soil to respond to agricultural management by maintaining both the agricultural production and the provision of other ecosystem services. Human-environment interactions are dominated by agriculture, which consumes more natural resources than any other human activity. This has raised concerns about agricultural intensification trajectories as related to planetary boundaries and land degradation tipping points. The adaptation of ecological concepts and principles to the design and management of agroecosystems through agroforestry is a key strategy contributing to address these sustainability concerns. The soil resource is central to agriculture and therefore sustainable agriculture is inherently dependent on soil health. The majority of ecosystem processes have the soil as the critical and dynamic regulatory center and soil biota play a key role in a wide range of ecosystem services that are essential to sustainable agroecosystems. Recognizing the great biological diversity in the soil, and the complexity of ecological interactions, the focus is on management of soil biota strongly linked to functions which underpin soil-based ecosystem services. Desired features of agroecosystems that promote soil biological activity, that in turn promotes ecosystem functioning will be discussed and illustrated with case studies. Farmers represent the largest group of natural resource managers in the planet and have a critical role to play in the agroecological transition towards sustainable land management. Farmers and other land managers need to be active players in the conservation and enhancement of soil health and soil-based ecosystem services. The participatory development of soil health indicators and monitoring systems that integrate local and scientific knowledge is a key component of the strategy to predict and adapt to land use change, agricultural intensification and environmental changes while moving from a reactive to a more proactive approach towards sustainable land management.

Room 301A

## B1. Transitioning to Better Water Balance and Light Valorization

Micro-climate impacts on coffee light, temperature and humidity regimes of trimming overstorey pine trees in East Java, Indonesia

Even Henrik Seyersted, Plant Production Systems, Wageningen University and Research, Netherlands

**\*Rika Ratna Sari, Wageningen University and Research, Netherlands**

Danae Ma Rozendaal, Wageningen University and Research, Netherlands

Danny Dwi Saputra, Wageningen University and Research, Netherlands

Cahyo Prayogo, Soil Science Department, Faculty of Agriculture, Brawijaya University, Indonesia

Simon Oakley, UK Centre for Ecology & Hydrology, United Kingdom

Didik Suprayogo, Brawijaya University, Indonesia

Meine van Noordwijk, World Agroforestry - CIFOR-ICRAF, Indonesia

Background: State-forest pine plantations on mountain slopes in densely populated Java have allowed farmers to grow coffee as understory crop, but without tree canopy management, light levels are too low. Objectives: Contribute to pine-tree canopy management that allows higher coffee production, without affecting soil protecting functions, by better understanding of microclimatic consequences. Methods: Long-term observation plots with 19-year old pine trees were split and lower pine branches to a height of 10m were removed in half the plot in the UB-forest (7o50 S, 112o35 E). Analysis of data from continuous recording from EasyLog Temperature & Humidity Loggers installed at 2 m height (above the coffee canopy) attached to tree stems, and a UA-002-64 Hobo Pendant light and temperature sensor on a 2 m pole in-between trees. Results: Light intensity was greater during the rainy season (Southern Hemisphere summer). Pine tree trimming increased light at coffee level by about 15% in both wet and dry season. Mean maximum and minimum air temperature for the complete dataset were 23.6 °C and 16.1°C, mean daily temperature range 7.5 °C and the warming rate was 1.00 °C/hr. Relative humidity varied from 75-95%, Vapour Pressure Deficit (VPD) from 9 to 75%. The trimmed treatment had a stronger effect on VPD during the rainy season where values were lower than for untrimmed trees. Discussion: Pine trees in dense stands tend to accumulate necromass on their lower branches. Trimming probably reduced interception of rainfall and post-rain evaporation from the canopy, beyond tree transpiration, potentially explaining the season\*trimming interaction. Increased light levels at the coffee canopy were associated with higher evapotranspiration demand for coffee, compensating the lower water use in the pine canopy. Conclusion: Trimming pine trees improved the light regime for coffee, while maintaining a buffered microclimate. Coffee productivity can increase over time, depending on coffee management.



### *Faidherbia albida* transpiration and canopy conductance in a reference agroforestry system of West Africa

\*Frederic C. Do, IRD, France

Mame S. Sarr, ISRA, Senegal

Khalisse Diouf, ENSA, Senegal

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Djim M.L. Diongue, UCAD, Senegal

Alain Rocheteau, IRD UMR Eco&Sols, France

Ibrahima Diedhiou, ENSA, Senegal

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Guerric Le Maire, CIRAD, France

Olivier Roupsard, CIRAD, France

*Faidherbia albida* is a key tree species of agroforestry systems in the semi-arid lands, well-known for its phreatophytic habit. Due to its reverse phenology (leafless in rainy season) no competition is expected with crops for soil water. However, little is known of *Faidherbia* transpiration and canopy conductance over seasonal conditions which prevents modeling water balance and response to drought. The on-farm study was conducted at *Faidherbia*-Flux1 in the population-health-environment observatory of Niakhar, Sénégal. Five mature trees were selected in the stand with a density of 6.9 tree ha<sup>-1</sup>. Sap flow, xylem and soil water content were continuously recorded over two years with meteorological conditions and complementary measurement of canopy leaf phenology, leaf area index and leaf water potential. Maximal transpiration estimated from sap flow peaked around 150 L tree<sup>-1</sup> day<sup>-1</sup> in the early dry season (December) for an average tree DBH of 60 cm and 200 m<sup>2</sup> of leaf area. The transpiration slowly decreased up to June before a sharp decrease following intense defoliation at the beginning of the rainy season in July. Predawn leaf water potential ranged between 0.25 MPA in early dry season and 0.45 Mpa in mid dry season, indicating a low water constraint throughout the dry season, likely related to an access to the groundwater. However, the reference canopy stomatal conductance per leaf area (at 1 kPa VPD) decreased from around 100 in early dry season to 50 mmol m<sup>-2</sup>s<sup>-1</sup> in mid dry season suggesting a significant constraint. Moreover, in both case, the canopy stomatal conductance was highly sensitive to VPD with a 50% decrease at 3 kPa. This study provides new bases for transpiration modeling of *Faidherbia albida* in agroforestry parklands. It particularly suggests to consider more importantly the influences of soil surface drying and VPD on transpiration regulation of *Faidherbia*.

### Grapevine in agroforestry: impact of trees on water stress, yield and grape composition

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Agroforestry is attracting more and more interest from grapevine growers, who hope to benefit from the climate protection provided by trees to adapt to climate change. Indeed the microclimate in agroforestry plot is likely to mitigate some of the adverse effects of climate change such as heat waves, drought or frost damage due to early budbreak. However, trees also create competition for light, water and nutrients so the overall effect of agroforestry on grapevine water stress, yield and

grape composition is difficult to predict. The objective of this work was to characterize the effects of trees on microclimate, light competition, water relationships, grapevine yield and grape composition. We followed 700 grapevine plants from 2 cultivars in 6 plots in the Restinclières agroforestry platform near Montpellier, over 3 years; 543 of these plants were cultivated in agroforestry (under stone pine or sorb trees), 158 were cultivated in full sun control. Measured variables included phenology, predawn water potential, water stress indicators, yield and yield components, grape chemical analysis, as well as environmental characterisation (microclimate, soil texture). Light availability varied along north-south transects between east-west oriented tree rows (Figure 1a). Although yield was reduced in agroforestry compared to full sun control, in particular for Syrah variety, no clear pattern was discernible across the transects (figure 1b). The effect of trees on grape composition varied between years and cultivars. These results indicate complex interactions between microclimate modifications and resource competition.

### Spectral composition of transmitted radiation in agrivoltaic vs. agroforestry systems and implications for understory crops

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Chad Higgins, Oregon State University

Light is usually the most limiting factor for understory plant growth in agroforestry systems, and also in agrivoltaic systems, depending on the arrangement of solar arrays (panel density), but there is virtually no information on light quality (i.e. spectral composition). Under tree canopies, the transmitted radiation becomes impoverished in certain wavebands and enriched in others, thus changing ratios between the different spectral components. The red/far-red ratio, for instance, decreases, often inducing morphological and phenological responses in understory crops, affecting their growth, radiation use efficiency and quality. We hypothesized that photovoltaic (PV) panels are relatively neutral absorbers, thus reducing transmitted radiation without substantially altering spectral composition. Thus, the objective of this study was to compare the spectral composition of the radiation transmitted under PV panels and under trees. Transmitted radiation was measured along transects between two adjacent rows of PV panels, and compared to radiation transmitted in alleys between rows of trees of different species. Measurements were taken at different times of day and different days during the year, using a spectrometer (LI-180, LI-COR, Lincoln, NE, USA), measuring radiation in the 380-780 nm waveband and its composition: near UV (380-400 nm), blue (400-500 nm), green (500-600 nm), red (600-700 nm), and far red (700-780 nm). Despite large changes in overall transmitted radiation along the transect in the PV array, the relative spectral composition was little affected. Particularly, the red/far-red ratio varied minimally along the transect, never dropping below 1, unlike under tree shade, where this ratio decreased strongly (>50%). Relatively unchanged spectral composition below the PV panels, compared to below trees, suggests that agrivoltaic systems might not stimulate shade responses in understory crops as much as agroforestry systems. The results highlight the importance of assessing spectral quality when comparing and optimizing these two production systems.

Farmers' Representative in this session: Juliana Pereira Pino, Brazil

Room 304A/B

## D4. Transitioning to a Viable Climate

Shelterbelts & other agroforestry systems: a natural climate solution opportunity for carbon sequestration and other co-benefits in agricultural lands

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Canada contributes significantly to world food production, but this has not occurred without environmental costs. The agro-ecosystem fragmentations and associated habitat destruction for monoculture production have contributed to a reduction of essential ecosystem services, such as carbon sequestration and refuge for beneficial insects and other wildlife. In central Canada, rising temperatures are linked to an increase in multiple-day precipitation events and recent large floods that have affected critical agricultural areas. To prevent further damage in Canada and beyond, we need to increase removals of carbon dioxide from the atmosphere, as well as reduce emissions from fossil fuels and land sector activities. Incorporating trees in agricultural lands as shelterbelts and other agroforestry systems has numerous benefits, such as carbon sequestration, improved soil productivity, clean air and water, and biodiversity conservation. We examined four of the multiple ways trees can be incorporated into agricultural lands: shelterbelts, tree intercropping (also known as alley cropping), riparian tree planting, and silvopasture. While millions of shelterbelt trees were planted across the three prairie provinces beginning in 1925 until 2013, other practices are yet to be adopted on a large scale in Canada. We will present the potential to expand the later three systems, whereas, for shelterbelts, we will present two scenarios: avoided conversion of existing shelterbelts and plantation of new shelterbelts. The discussion will highlight the scope of each agroforestry system, carbon sequestration potential, other co-benefits, and area of opportunities in Canada.

Advancing agroforestry adoption: understanding perceptions of windbreaks in the United States and Canada

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Blair English, Agriculture and Agri-Food Canada, Canada

Henry de Gooijer, Agriculture and Agri-Food Canada, Canada

As nations look for strategies to advance climate smart agriculture, renewed interest has been placed on windbreaks, which can offer climate mitigation and adaptation benefits. An understanding of both producer and natural resource professional

perceptions of benefits and costs of adoption is needed to effectively incorporate windbreaks as a part of a climate-smart agriculture strategy. Understanding their perceptions is particularly important in the U.S. and Canada, where many producers have aging windbreaks that need renovation or complete replanting. This raises an important question about whether producers in these countries still believe that windbreak benefits outweigh the costs, especially as they adopt new farming practices, use new crop cultivars, implement new farm technologies, and adjust management in the face of a changing climate. To address this question, the United States Department of Agriculture National Agroforestry Center (USDA NAC) and Agriculture and Agri-Food Canada (AAFC) conducted a systematic review of the literature for windbreak/shelterbelt adoption studies for their respective countries. Results will be presented jointly from both the United States and Canadian perspectives, comparing how each country's producers and natural resource professionals' value this agroforestry practice. The presentation will end with a discussion of future research needs related to windbreak adoption in the U.S. and Canada.

### Agroforestry For Climate Risk Management: Effectiveness of Windbreaks in Reducing Crop Loss in the Midwest, USA

\*Bhuwan Thapa, University of Missouri, United States

\*Sarah Lovell, University of Missouri, United States

Zhen Cai, University of Missouri, United States

K.S.M. Tozammel Hossain, MU Institute for Data Science & Informatics, University of Missouri, United States

Mi Young Kwon, MU Institute for Data Science & Informatics, University of Missouri, United States

Wind damage costed the U.S. government approximately \$1.2 billion in crop insurance payments between 2015 and 2020, of which around half were paid for damage claims in the Midwest region. Windbreaks consist a strip of trees planted on farms, to protect crops or livestock by altering wind flow and microclimate. Using the case of two Midwestern states, i.e., Nebraska and Kansas, this study evaluates the performance of windbreaks in reducing wind-related crop loss for corn and soybean production. We quantified the extent of windbreaks and tree cover on and around agricultural land using high-resolution landcover maps based on imageries from National Agriculture Imagery Program and Moderate resolution Imaging Spectroradiometer (MODIS). The county-level monthly wind-related crop loss payments were based on crop insurance payments derived from U.S. Department of Agriculture Risk Management Agency. We developed a mixed-effect econometric model to determine factors that affect crop insurance payments by including windbreak density, average wind speed during growing season, and extreme wind erodibility index as independent variables. Our preliminary findings show the inverse relationship between tree cover on agricultural land and wind-related crop loss. The development of cost-effective monetary valuation for windbreaks incorporating wind-related crop loss is critically needed to promote nature-based solutions for wind risk management.

### Modelling more complex and various agroforestry systems with the upgraded Hi-sAFe v4.2 agroforestry biophysical model

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Marie Gosme, INRAE, France

Kevin Wolz, Savanna Institute, United States

Christian Dupraz, INRAE, France

The Hi-sAFe model was first implemented in 2004 with the aim to predict the behaviour of agroforestry systems by simulating tree-crop interactions in 3D. It has been continuously improved since then. Over the past 3 years, significant advances were achieved in order to make the model more inclusive (to all sorts of agroforestry systems), more reliable and easier to use. The model is now routinely used for understanding tree-crop interactions in AF experiments, to assess the impact of Climate Change on AF systems or to predict AF productivity and ecosystem services in various conditions. The Hi-sAFe model is now available on 3 operating systems (Windows, Mac and linux). It is easy to install and comes with an English user manual. An R package named Hi-sAFeR is available as a free license. Hi-sAFeR is a powerful tool for assisting in the design of virtual agroforestry experiments and the graphical analysis of results. The model is also available on the MUSE computing cluster hosted at Montpellier University to perform large sets of simulations requiring more computing resources than a PC. A particular effort of traceability was made on the versioning issue: source code, parameter files, bug tracking and improvement logging. All simulations are now stored as self-contained units allowing a rerun any time in the future, which is very useful with models that evolve constantly. Several code modules were added to increase the versatility of the model. They include: • a tree fruit module to simulate AF systems with fruit tree plantations • a tree nitrogen fixation module to simulate AF systems with N-fixing trees • a tree pollarding module to simulate pollards or fodder trees • a snow module to manage cold climates conditions. Hi-sAFe includes the Stics crop model. The coupling with STICS was improved to refine the interactions between trees and crops. Tree pruning debris, leaf fall and dead roots residues are now fully incorporated into the soil for humification and mineralization. Automatic irrigation and fertilization triggers can now be synchronized on the cropped area. Crops water and nitrogen stresses calculations were also improved. Further improvements are considered, including the upgrade of the STICS crop model with its version 10 that will provide a better simulation of soil processes. This is required to assess C sequestration and soil fertility evolution in agroforestry systems.

### Smallholder forest and farm producers turning climate change challenges into adaptation and production opportunities in Ghana's semi-arid savanna regions

\*Mark Kebo Akparibo, Tele-Bere Green AgroFarms, Ghana

Climate change variability has affected agriculture and forest-based production and agroforestry systems and value chains in Ghana's semi-arid savanna regions contributing to ever-widening poverty, food and nutrition insecurity forest and land degradation and deforestation. Water remains a critical resource for agricultural production in this part of Northern Ghana. This is further underscored by the fact that the area has only one raining season of just three to four months annually. This situation is a major factor contributing to rural-urban migration of the youth from Northern Ghana to the south in search of menial jobs. The long-term goal is to turn the dry, degraded and deforested landscapes in the northern savanna belt of Ghana to green, integrated and climate resilient production landscapes for smallholders to provide: (1) food and nutrition security for their households, (2) secure and commercial carbon assets for accessing climate financing and, (3) sustainable, commercially viable, bankable and profitable forest and farm businesses for multiple value chains (basket of products); with year-round available and accessible water. The strategy will promote deforestation-free year-round production, landscape restoration, agroforestry, building of carbon assets and multiple value chain products that enables smallholders to well adapt to the effects of climate change and build back better. This innovation applies the lessons of the existing community-managed small town and rural water systems in Ghana that has been successfully applied to provide domestic water needs of various rural communities. This Project intervention is being piloted in selected landscapes covering multiple communities in the worse affected areas of the five regions of the northern savanna belt of Ghana. The pilot works in the Upper East, Upper West and Northeast Regions that are usually the worse hit by the perennial floods and benefits up to 5000 smallholder forest and farm producers and their households.

Farmers' Representative in this session: Mark Kebo Akparibo, Ghana

Room 303A

## G2. Transitioning to a Viable Society

Are agroforestry and social goals mutually exclusive? Exploring inclusive businesses in Peru's cacao, coffee, and oil palm sectors

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Luca Zambrino, University of Bern, Switzerland

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Sustainability standard certification is the main governance approach aimed at encouraging the adoption of agroforestry practices and at enhancing human well-being in global agri-food supply chains. However, evidence points to limited and sometimes even adverse effects of certification schemes on the farmers, worker, and community wellbeing. Alternative or complementary approaches may challenge these barriers with the expectation that they will achieve the same sustainably goals including the adoption of agroforestry practices. Inclusive business strategies are gaining relevance as such an alternative approach taken by private sector actors. However, since certification and inclusive business strategies are studied in isolation, it remains unclear whether inclusive businesses can overcome the barriers to well-being impacts that many certification schemes face while ensuring the adoption of agroforestry and agroecological practices that certification schemes have achieved. This study explores to what extent and how inclusive business strategies are effective in achieving positive well-being and sustainability impacts. We present an assessment of nine selected cases of inclusive businesses from the cacao, coffee value chains in Peru. Results show inclusive business strategies offer entry points to better well-being outcomes for smallholders. However, they are no better than certification schemes in encouraging the adoption of agroforestry practices and in some cases fare worse than certification schemes in influencing their adoption. We conclude that the institutionalization of environmental justice inclusive business strategies and certification schemes may be better at achieving the dual goals of encouraging the adoption of agroforestry adoption and enhanced human well-being in agri-food systems, but these relations need greater, multi-method analysis.

Biomass production vs firewood consumption: caring for its equilibrium in agroforestry parklands of West African savanna

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In the Savannah of West Africa, the predominant land-use is agroforestry parklands. There, firewood remains as the most demanded source of energy for cooking. Rising deforestation, parklands degradation and population growth sustained

predictions of a firewood gap, which so far did not crystallize. As quantitative assessments are sparse and the social and environmental components of firewood gathering poorly accounted, we have quantified the stocks of firewood, estimated the firewood gathering, and measured its consumption in two rural catchments of Benin and Burkina Faso. Data collection methods comprised botanical inventories, trees' biomass estimation, identification of householders' collection habits, and measurement of households' firewood consumption. Analyses included descriptive statistics (frequency of favored species, t-test for seasonal differences, and probability distribution for per capita firewood consumption); land-use classification (upscaling of biomass stocks); and discourse analysis. Our findings show a drifting in the preference for firewood-provider species either by resource exhaustion or as preventive strategy. Quantitatively, tree biomass becomes a misleading proxy of firewood availability, as non-tree firewood species and non-used larger individuals distort sampling. Our estimated per-capita consumption rounds 1kg per day, which is inferior to precedent estimations. Commercial demand of firewood is disproportional, reaching up to one third of the whole. These results recall for re-assessing the importance of previously considered key firewood-species, the biomass of parklands as proxy of firewood stocks, and the per-capita estimated consumption. As firewood gathering entrenches communal lands and even natural reserves, its impacts surpass the ecological realm, towards weakening community norms and social cohesion. Despite their major share, the commercial demand of firewood, remains largely unaccounted, and its triggering role of detrimental firewood markets. Interdisciplinary studies, combining quantitative and qualitative methods are worth in offering compelling evidence on the dynamics of complex issues, such as the firewood offer and demand in parklands agroforestry systems.

### Advancing urban agroforestry: a case study of federal efforts in the United States

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Richard Straight, USDA National Agroforestry Center, United States

Lord Ameyaw, Nebraska Forest Service, United States

Today, 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050. With more people living in cities, there is an increasing need to support sustainable and resilient urban agriculture. While agroforestry has been incorporated into urban agriculture around the world, it has received less attention and support. Recognizing the growing importance of urban agroforestry, the United States Department of Agriculture (USDA) has increased financial and technical support through new funding sources and staff. This presentation describes federal support for urban agroforestry in the U.S.A., as well as examples of how local organizations are using that support. The 2018 Farm Bill directed USDA to create the Office of Urban Agriculture and Innovative Production (UAIP) to better focus on the needs of urban farmers. This office manages a competitive grants program, which increasingly offers support for food forests and other urban agroforestry efforts. UAIP is establishing a federal advisory committee and Farm Service Agency county committees focused exclusively on urban agriculture. It also develops other policies and resources to assist urban producers. The United States Forest Service, in partnership with State Forestry Agencies, has long supported urban forestry efforts carried out by cities, states, communities, and other organizations through its Urban and Community Forestry Program. These urban forestry efforts are increasingly directed towards food forests and other food-producing systems. Finally, with funding support from the UAIP, the USDA National Agroforestry Center has supported the development of agroforestry outreach materials that describe best management practices related to existing and new urban agroforestry systems or modifying urban agriculture systems to incorporate agroforestry practices. The goal of this effort is to help the public, technical assistance providers, and others better understand how urban agroforestry can benefit agriculture, communities, and conservation.



## Indigenous Roots of Agroforestry and the Skarù-r Food Forest Project - Community Engaged Indigenous Agroforestry at the Tuscarora Nation

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Agricultural research often overlooks critical social justice implications underlying the history of dispossessed land and appropriated Indigenous crops. The Skarù-r Food Forest is a community-based aspect of a doctoral research program studying how nut trees contribute to Indigenous food sovereignty and climate smart agriculture, in what is today New York State. As one of the most nutritionally dense plant-based foods, nuts were important components of food economies among Indigenous peoples in the Eastern Woodlands, notably the Haudenosaunee (People of the Longhouse, also known as "Iroquois"). Archaeological, ethnographic and historical-ecological evidence indicate that the Haudenosaunee may have managed forests partly to favor such nut trees. However, contemporary food sovereignty efforts have mostly focused on maize and other annual crops. Although these crops are culturally foundational, nuts can play an important role in food and language revitalization efforts within contemporary Haudenosaunee territories. Here we discuss a variety of approaches used to engage Tuscarora Nation members with culturally relevant approaches to agroforestry. By addressing social justice concerns within agricultural science, we demonstrate how the Skarù-r Food Forest Project can provide a methodological testing ground for Decolonial Participatory Action Research that expands ongoing food sovereignty, community health and education initiatives.

Farmer's video: agroforestry in Brazil

Room 301B

## 11. Transitioning to Viable Policies

### Institutional factors influencing the social, ecological and economic resilience of local Malagasy communities through agroforestry

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Nancy Gélinas, Université Laval, Canada

Local farming or forestry communities from different ecological regions of Madagascar are effective or potential practitioners of agroforestry to build or strengthen their social, ecological, and economic resilience. The objective of this communication is to share the multilevel institutional factors relevant to agroforestry, in favor or against family and community socioecological resilience, raised by grassroots actors and their partners in Madagascar. Methods: A qualitative and inductive approach was used to elicit the opinions and practices of the members of a community-based national network on the institutional factors influencing their economic, social and ecological resilience. The factors were then compared with the approaches and concepts used by their partners in the field to highlight institutional inconsistencies. Results: The study found that the most important resilience factors are those that link at least two or more elements of their territories-of-life: agricultural land, forest, water, and space for living, socio-cultural, economic and governance matters. The communities that have succeeded in developing and surviving crises are those that have been able to set up effective

institutions to manage the various elements. Moreover, actors are represented and share an integrated vision of their living territory in a governance institution. They are also linked to networks at the meso and macro levels to consider factors that cannot be controlled locally, such as global market pressures or non-compliant top-down approaches. Discussion and conclusion: Communities are responsible for bringing their cultural and institutional knowledge, skills, and attitudes to bear in the dissemination of agroforestry practice and in their collaboration with scientific, technical, and financial partners. The latter are responsible for integrating them in any study and approach and aiming at their autonomy and resilience in the short and long terms.

### Agroforestry Policy Development in Switzerland

\*Sonja Kay, Agroscope, Switzerland

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In Switzerland, the Agenda 2030 and the Sustainable Development Goals come to live within the Action Plan 2021-23 for Sustainable Development 2030 released by the Federal Government. Herein “trees outside forest: urban forestry and agroforestry systems” is named as one measure to account for carbon sequestration, biodiversity enhancement, mitigation and adaption of climate change. The Action Plan aims involving relevant actors from government, science, and practice to design a sector-independent strategy and develop innovative approaches to boost tree planting and ecosystem services. In addition, Swiss agroforestry in agricultural land is highlighted as tool for environmental resource protection by the Federal Agricultural Policy. Modern agroforestry systems such as alley-cropping systems, fodder hedges, or wooded pastures are favoured by Swiss farmers as they combine environmentally friendly agriculture without substantially limiting agricultural production and being rentable. However, open questions still exist. Which system is most beneficial for soil or water protection? Which ones can provide high biodiversity enhancement? And how to measure and quantify these effects? Farmers and policy makers require proper answers for long-term decision making. Preliminary results are delivered by a Swiss Resource Project “Agro4esterie” launched with special focus on Swiss climate and policy. Herein 100 farmers established agroforestry systems in agricultural land suffering environmental deficits. Limits for environmental pressures were defined by the Agricultural Environmental Objectives. The forthcoming of the agroforestry systems in addition to the environmental, economic, and social outcomes will be monitored within in the following 8 years. Action Plan activities together with outcomes of the monitoring will provide valuable information to (re)design national agricultural policies and enable to develop strategies geared to local conditions and environmental targets.

### Analyzing agroforestry at a farming system scale in Switzerland exploring levers and constraints to its adoption

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Johan Six, Swiss Federal Institute of Technology, Switzerland

Dominique Barjolle, Swiss Federal Institute of Technology, Switzerland

Agroforestry is gaining momentum in temperate context. While it appears that money may not be the only factor influencing adoption (Sereke et al., 2016), the actual influence of agroforestry on the technical and economic functioning of the farming systems is scarcely known, especially in Switzerland. A transdisciplinary project has been initiated to promote and evaluate agroforestry in French-speaking Switzerland. Our research explores the methodological difficulty of reaching a farming system and territory level of understanding of agroforestry dynamics. We compared the population of farming systems

involved in the project to that of all farming systems in the area. We performed a cluster analysis using a k-medoids algorithm to provide an initial typology of farms, before conducting interviews to better qualify and quantify these farming systems from a technical and economic perspective. The cluster analysis revealed a diversity of farming system types, focused on organic production, direct selling, the production of fruit and vegetables, and with relatively low surfaces compared to the general situation in the cantons involved. Other particularities include their relatively young age and specific working skills with trees. It appears that farming systems practicing agroforestry are very specific and may have more technical ease and economic added value gained by a partial switch to agroforestry. Our work revealed the relatively large diversity of farming systems engaged in agroforestry within the project area. However, we could also observe how very particular all these different farming system types were, being overwhelmingly labelled as organic or integrated production, and practicing direct selling. Agroforestry may not yet be perceived as a mainstream practice by most farmers, and require further knowledge and guarantees for farmers. Our work will now question added value and revenue discrepancies induced by agroforestry for various farming system types, to discuss this as a hypothesis for agroforestry adoption in Switzerland.

### Agroforestry in Quebec and the role of agri-environmental incentives

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Agroforestry practices such as hedgerows and shrubby riparian strips have been encouraged by public authorities in Quebec as means to reduce diffuse pollution coming from agricultural lands, while also diversifying the agricultural landscape, especially in intensive cropping systems. The main tools to encourage such practices are voluntary mechanisms that create financial incentives and provide subsidies for farmers, such as the agri-environmental program “Prime Vert” managed by the Quebec government. Our work aims to evaluate the impact of such program in encouraging the uptake of agroforestry measures by looking at the history of its implementation, the type of practices encouraged on the ground, as well as the state of participation of farmers across Quebec. To do so, our analyses is based on data provided by the Ministry of Agriculture of Quebec in terms of expenses and projects funded over the years. Our work discusses the socio-economic and institutional factors that explain the low engagement of farmers toward these type of incentives, based on the literature on agri-environmental programs and payments for ecosystem services. The analysis of current programs provides new public policy perspectives to scale-up the adoption of agroforestry practices, particularly in intensive agricultural landscapes, where important tradeoffs might exist between continuing intensive production in the dominant paradigm and the diversification of land uses as a means to increase the provision of ecosystem services.

### Agroforestry development in the Netherlands: bottlenecks and opportunities in policy issues

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Eelco Buunk, Van Hall Larenstein University of Applied Sciences, Netherlands

René Van Druenen, AGROBOSBOUW NL, Netherlands

Agroforestry in the Netherlands is taking a momentum, the professional practice is slowly but increasingly adopting agroforestry as an agricultural practice and clear government efforts are acknowledging the importance of agroforestry as a climate adaptive option that aligns with national goals. However, farmers are still facing a wide variety of challenges which

also lie on policy issues. The objective of this paper is to evaluate the current bottlenecks and barriers that farmers perceive and experience in the implementation of agroforestry in the Netherlands. This review has been carried out building upon the results of an online survey where perceived bottlenecks were identified (total N=3,500 farmers and other stakeholders). Based on the aforementioned results the current relevant EC's Common Agricultural Policy (CAP) normative provisions and the Dutch national rules and regulations that promote agroforestry are referred. We also identify the potential bottlenecks that the transition to the new CAP imposes to the implementation of agroforestry. Main bottlenecks fell under three categories, i.e. issues about technical knowledge, business models, and rules and regulations. Main subjects that were raised under the rules and regulations category were unclarity on current provisions at EU and national level (e.g. CAP), registration of crops under agroforestry and related subsidies, governance at national and provincial level. Thereafter the EC's Common Agricultural Policy (CAP) normative provisions and the Dutch national rules and regulations that are acting as barriers were linked to these raised subjects. Various CAP provisions concur with previous identified policy issues that are shared with other EU member states, however many require adaptations of rules and regulations at the national, provincial and municipality level and a coordinated governance among these levels.

Farmer's video: agroforestry in Cameroon

Room 203

## L5. Which Agroforestry for Commercial Perennial Crops and Trees?

Agroforestry systems in the humid East Coast of Madagascar: between food self-sufficiency and high value chains for export

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Aina Rabodomanantsoa, CHTT, Madagascar

Gaylor Razafimamonjison, Université d'Antananarivo, Madagascar

Fawbush Razafimbelo, Université d'Antananarivo, Madagascar

Michel Jahiel, CIRAD, Madagascar

Pascal Danthu, CIRAD, France

Madagascar is one of the leader producer and exporter of lychee, clove and vanilla in the world. These three crops were introduced and developed on the east coast of Madagascar more than a century ago in the context of colonial agriculture. Since then, innovative complex agroforestry systems (AFS) were designed by smallholders that associate a high diversity of species and constitute the basis for the export of these products. In Atsinanana and Analanjirofo (literally : clove forest) regions, these AFS not only combine clove and lychee trees but also a high diversity of fruit and forest tree species, and herbaceous crops that are or have been of strategic economic importance such as vanilla, coffee or pepper. Some crops are also intended to feed the local market or the on-farm consumption as breadfruit, jackfruit, or sugarcane. Moreover these AFS provide a wide bunch of ecosystemic services for local population: the diversification process improves socio-economic

resilience of vulnerable farmers by balancing incomes and providing numerous cultural, social and environmental services. The paper, based on numerous farm surveys and field observations in the areas of Toamasina and Fenerivo, proposes a typology of AFS, mainly characterized by structures (species composition and association) and practices. The diversity observed contributes significantly to the resilience of the socio-ecological system. In the future, the orientation of these socio-ecological systems toward more resilient trajectories will highly depend on the development of their capacities to reconcile the constraints of highly competitive international value chains such as lychee, clove or vanilla, which are greatly influenced by the demand located in developed and emerging countries, with the complexity of the existing systems.

### Using functional traits to assess crop-environment interactions in agroforestry systems

Marie Sauvadet, CIRAD, France

Adam K. Dickinson, University of Toronto, Canada

Eduardo Somarriba, CATIE, Costa Rica

Wilbert Phillips-Mora, CATIE, Costa Rica

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Selecting crops that express certain reproductive, leaf, and root traits has led to diverse crop domestication syndromes. However, scientific and informal on-farm research has primarily focused on understanding and managing linkages between only certain traits and yield. There is strong evidence suggesting that leaf functional traits—i.e., the morphological (e.g., specific leaf area [SLA]), physiological (e.g., photosynthesis), and chemical (e.g., leaf nitrogen (N) concentrations) traits of plants—have also been influenced by domestication, and reflect trade-offs and constraints among aspects of crop biology and agroecosystem environmental conditions. Yet, our understanding of how agroforestry systems influence trait expression and relationships remains limited. We measured nine morphological (thickness, area, SLA), physiological (maximum photosynthetic rates, stomatal conductance, and water-use efficiency [WUE]) and chemical traits (leaf carbon (C) and N concentrations, C:N ratios), on six cultivars grown in two clonal gardens with distinct environmental characteristics (i.e., a “Mild dry season” with near-optimal cacao growing conditions, and a “Harsh dry season” site with sub-optimal conditions). Genotype x Environment interactions were detectable in leaf functional trait expression, though these interactions varied strongly with the group of traits being evaluated; morphological traits varied widely among clones but these differences were robust across sites, while physiological and chemical traits significantly differed between clones, though inter-clonal differences varied depending on sites. Specifically, SLA increased with the clone productivity potential at both sites, while the least productive clones exhibited higher trait variation with a given site. Our results suggest that evaluating functional trait variation informs our understanding of Genotype x Environment interactions in crops widely cultivated in agroforestry systems. These results also suggest that integrating theory and techniques from functional trait ecology into agroforestry management design and crop selection, can contribute to optimizing agroforestry production under environmental constraints.

### Comparative assessment of the duramenization of agroforestry hybrid walnut trees with their respective forest controls

\*Lucie Heim, Arts et Métiers, France

Kévin Candelier, Cirad, France

Loic Brancheriau, Cirad, France

Rémy Marchal, Arts et Métiers, France

Nabila Boutahar, Cirad, France

Eric Badel, INRAE, France

Louis Denaud, Arts et Métiers, France

The quality of agroforestry trees is little studied, even though these trees develop in spatializations far removed from those of conventional stands. This study focused on the quality of hybrid walnut wood from agroforestry systems, walnut wood quality being strongly defined by its aesthetic aspects. This notion is particularly determined by the woody material color, directly linked to its duraminisation. This phenomenon of ageing is monitored among other things by the environmental growing conditions. This work consisted in a comparison of the duraminisation biological process through the quantification of extractives contents of hybrid walnut trees (*Juglans regia* × *nigra* cv. NG23) from agroforestry systems (AF) and from forest controls (FC) plots, both located in Restinclières Agroforestry Platform (South of France). Two successive soxhlet extractions, using water and ethanol solvents, were performed on samples taken across the width of the trunk in order to obtain a radial distribution of the extractive fractions of AF and FC walnut trees. These quantitative analyses were coupled with infrared spectroscopy (NIRS) measurements in order to develop a rapid system to evaluate the chemical properties of agroforestry walnut wood. The first results obtained indicate that there is no significant difference between the amount of extractives in the trunks of AF and FC walnut trees. Moreover, since the walnut trees studied were 25 years old, the duramenization process was not yet visible to the naked eye. However, we observed a greater quantity of extractives compounds in the middle area of the trunk than at the periphery for both the AF and FC plots (Figure 1) which suggests that the hardening process is underway even if the phenomenon is not visible. The next step of this study will be focused on the screening of heartwood of each studied walnut samples, using a photographing cross sections of their trunk with a hyperspectral camera system. Such analyses could be an interesting to observe the chemical composition variation across the radial orientation of the tree and could be able to estimate if the development conditions in the agroforestry environment has an impact on the walnut trees heartwood formation process.

### Cacao custodian farmers: a case study from Cusco, Peru

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Evert Thomas, The Alliance of Bioversity International and the International Center for Tropical Agriculture, Peru

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Alain Olivier, Université Laval, Canada

The conservation of agrobiodiversity most often relies on the work of custodian farmers. These farmers maintain, adapt, and promote varieties, thus playing a major role in conservation. Their roles have been studied for various crops and perennial species, but we have little to no information on their contribution to cacao conservation. We investigated cacao custodian farmers in Cusco, Peru, to understand their common traits in the preservation of cacao Chunchu, a renowned landrace from this region. Following questionnaires and/or interviews with different farmers in the region, 7 were identified as custodian farmers: they owned old chunchu cacao trees, promoted its use, maintained different cultivars (e.g. común, señorita, cascara de huevo, de montaña, etc.), and were recognized by their peers for this conservation work. We found

that these farmers had key characteristics in common: they want to maintain a heritage that they perceive as important, and they identify with their landrace, judging it as the best or one of the best cacao. A sense of tradition also seems to be important to these farmers, as they have perpetuated their variety even when they were advised by agricultural advisors to replace it with improved hybrid varieties. However, this does not necessarily mean that this variety is maintained only in traditional systems, but rather that the approach to its conservation is fueled by a vision that tends towards a common heritage approach. Although they may have concerns about yield and profitability, these farmers approach their cacao production with more than just these criteria in mind, but with a perspective of a legacy.

### Local knowledge and relational values of Midwestern woody perennial polyculture farmers can inform tree-crop policies

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Mollie Chapman, Department of Geography, University of Zurich, Switzerland

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Kai M.A. Chan, Institute for Resources Environment and Sustainability, University of British Columbia, Canada

The US Midwest is emerging as a hotbed of farm-scale woody perennial polyculture enterprises, but they are currently only a tiny fraction of the landscape. Understanding how such approaches might be scaled up for food production and ecosystem services thus requires learning from the farmers that are at the forefront of the transition of land to woody perennial polyculture to answer a range of questions: What unique management knowledge is being implemented by farmers to manage complexity on multiple scales? What key challenges have farmers faced? And what values and motivations underpin these fledgling efforts? From 13 interviews with 18 midwestern perennial polyculture farmers, we found that they largely used a small portion of their farm's land for their perennial enterprises, and did not earn a large portion of their income from them, though this was projected to increase as trees matured. Through experimentation, innovation, and farmer networks, the farmers had amassed unique management expertise for balancing diverse crops and livestock within multifunctional tree crop systems over time and space, an area largely absent from mainstream agricultural science and policy. The barriers these farmers report facing are largely economic rather than biophysical, involving access to capital, insurance, mid-sized markets, and regional processing infrastructure, as well as government programs mis-matched with perennality. Cross-cutting these topics, farmers sought to fulfill values anchored in their relationships to land, to community, or to both. The values of long-termism, learning and sharing, diversity, stewardship and care of farmland, connection to nature and wildlife, self-sustenance, other-sustenance, and eudaimonia were embodied and expressed in farmer decisions. Economic and agrarian policy and program development for multifunctional tree crop systems should a) be designed to align with farmer's values and motivations and b) take advantage of their expert systems knowledge to drive appropriate and successful sustainable transitions.



Room 204A

## N1. Which Agroforestry for an Edible Food Forest?

### A Nourishing Forest

**\*Marie Danielle Ndiemba, Chamber of agriculture, Ficheries, livestock and Forestry of Cameroon, Cameroon**

Emmanuel Kuh, Chamber of agriculture, Ficheries, livestock and Forestry of Cameroon, Cameroon

Beko'o Abondo Alain, Chamber of agriculture, Ficheries, livestock and Forestry of Cameroon, Cameroon

Mélanie Rosine Tsewoue, Université de Dschang, Cameroon

As its name suggests, the Chamber of Agriculture, Fisheries, Livestock and Forests of Cameroon (CAPEF) plays an important role in the Forestry sector in Cameroon. It is interested in the sustainable exploitation of the forest, forest protection and forest regeneration. This way it strives for the maintenance of the ecological balance and biodiversity, and engages in the fight against climate change. Apart from their great role in the fight against climate change, most forests in Cameroon have another important role as sources of nourishment, especially to communities living within or around them. The forests are relied on for NTFPs such as food, fruits, honey, medicines, wine, as well as construction materials and other timber products. Today, nourishing forests are taking a heavy toll from over exploitation as the forest products are marketed to fast expanding markets and even exported. In this abstract, CAPEF has adopted the objective of sustaining the nourishing forest. It intends to do this through the organization of the forestry sector all over the national territory. Activities involved shall include: holding concertation meetings with all actors; holding sensitisation meetings with forest actors and communities; providing trainings on tree domestication and installation of demonstration farms, including tree nurseries; trainings on collection, processing and marketing of NTFPs; restructuring of the sector from Divisional to National level; functionalization of the sector. These activities will result in sustaining the forest thus sustaining lives and livelihoods. There will be regular availability of planting materials for forest regeneration. Fruit trees and other nourishing plants are introduced and planted in forests or forest peripheries as the case may be, to further beef up the nourishing capacity of the forest. An organised forest sector in Cameroon will guarantee sustainability and enable local communities to continue enjoying forest products while respecting and protecting the forest.

### Forest use and management capacity assessment for forest-based livelihoods and climate resilience in Mchinji and Phirilongwe Forest Reserves, Malawi

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Paxie Chirwa, University of Pretoria, South Africa

Folaranmi Babalola, University of Ilorin, Nigeria

The world poorest live close to and depends on forests for livelihoods as well as coping strategy for the impacts of climate change. However, forest use and capacity of the forest-based households to sustain their livelihoods in the face of climate change is not well understood. We assessed forest use and management capacity of forest-based residents in Mchinji and Phirilongwe forest reserves, Malawi. Purposive sampling was used to select key informants while household surveys (n=422) was employed to sample household heads or older member of the household. Cross tabulation of frequencies, Pearson Chi-square tests, and Binary logistic regression test were employed in data analysis. Results show that forest products contribute over 90% of the forest-based households' subsistence and above 50% of the households' income generation. Firewood ranked the highest in contributing to household income. The utilization of forest products in times of erratic rainfall, serious

droughts and strong winds increase between 76-93% in Mchinji and 65-70% in Phirilongwe Forest Reserves. Furthermore, negligible proportion of the respondents in both study sites possessed forest management and forest business related skills. Increasing forest-based household size above six (6) (OR=1.567, CI=0.984-2.494) and the possession of livestock keeping skills (OR=2.080,  $p = 0.003$ ) significantly increased their likelihood to participate in forest management activities. However, gender was less likely to influence the likelihood of respondent's participation in forest management (OR=0.602,  $p=0.032$ ). About 71% and 53% of the respondents in Mchinji and Mangochi respectively were significantly not satisfied with decisions made by their local leaders on forest management ( $p=0.000$ ,  $X^2=23.89$ ,  $DF=4$ ). The inadequate capacity and ineffective participation in forest management threatens the sustained contribution of the forest-based livelihoods. We recommend awareness campaigns and technical skill trainings that will promote sustainable forest resource utilization and enhance their capacity to participate in forest related business and management.

### Agroforestry potential of some native miombo species: possible applications in rural development and forest restoration projects in southern Malawi

\*Stephane Person, Forest Goods Growing, France

Kennedy Mandala, Zankhalango, Malawi

Peter Kandiado, Zankhalango, Malawi

Wilson Kanthiti, Zankhalango, Malawi

This agroforestry elucidates some of the key impacts of agroforestry and attempts to build an understanding on various agroforestry initiatives implemented in the past and present in Malawi and point out what has worked well and potential constraints to scaling up. Miombo is the Swahili word for *Brachystegia*, one of many species found across the transboundary ecosystem that describes the vastest dry forest biome in southern Africa, stretching over seven countries; Angola, Democratic Republic of Congo, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe (Ribeiro et al., 2016). It is estimated that the Miombo woodlands/species such as Baobab, Tamarid (*Tamarindus indica*), *Azanza garckeana*, *Annona senegalensis*, *Lonchocarpus capassa*, *Acacia polyacantha*, *Uapaca kirkiana*, *Faidherbia albida* – through their numerous goods and services which include various Non-Timber Forest Products (NTFPs) (e.g. insects, mushrooms, fruits, tubers, medicine, fodder, honey, seeds) and wood fuels, sustain the livelihoods of more than 100 million rural poor and 50 million urban people (Ryan et al., 2016; Syampungani et al., 2009). Despite the fact that many indigenous fruit trees such as *Sclerocarya birrea*, *Azanza garckeana*, *Parinari curatellifolia* and *Uapaca kirkiana* and fertilizer/manure providing trees such as *Lonchocarpus capassa* can play an important role in food and nutrition security as well as poverty alleviation. They are underutilized as they are not significantly incorporated in agroforestry practices. Various projects carried out over the previous decade have shown spreading applications in rural development projects (e.g. the Zankhalango cooperative for the production of baobab, and tamarind and for the restoration of forest ecosystems. There are many challenges to sustainable management of the miombo woodlands, which include: • Lack of an enabling policy environment • Unsustainable management of Miombo woodlands • Limited willingness and ability to pay for and access to energy-efficiency technologies • Inadequate awareness and information • High poverty levels • Conflict between Agric and Forestry • Scarcity of seed centers in the districts.

### Chamugrö: An ancestral agroforestry system from the indigenous Bribrí-Cabécar culture in Talamanca, Costa Rica

\*Fabricio Camacho, Centro Científico Tropical, Costa Rica

Alexander Gonzalez, Centro Científico Tropical, Costa Rica

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Carlos Hernández, Centro Científico Tropical, Costa Rica

The value of traditional knowledge in agriculture and forest management from the indigenous cultures is incalculable worldwide. In Costa Rica, little importance has been paid to this knowledge, causing its degradation and extinction. UCANEHU, which represents “the union of the Bribrí and Cabécar cultures” is an indigenous farmer’s association with more than 200 members from the Talamanca region in South-eastern Costa Rica. They are a pioneer organization actively promoting the preservation and optimization of the Chamugrö, which is likely one of the first forms of agroforestry in Costa Rica. This ancient agroecosystem is unique in the sense that it represents an expression of the local indigenous culture and traditions. It has proved to be capable of sustaining these indigenous communities not only with a stable source of food security, construction materials, fuelwood, and resilience during environmental and socioeconomic crises, but it is also perceived as an effective tool for biodiversity conservation and climate change mitigation and adaptation. Due to economic and market pressures, the inception of conventional agricultural practices in the indigenous territories is threatening the ancestral production methods. Strategic actions must be taken to safeguard this knowledge and prevent its loss. This study elucidates the structure and composition of the Chamugrö in order to create a foundation of knowledge to extrapolate its adoption outside of the Talamanca region in three biological corridors managed by the Tropical Science Center (TSC) in Costa Rica, as a mechanism to ensure its preservation and to expand its reach. Precise information about the Chamugrö’s structural configuration will allow TSC’s agroforestry team to identify opportunities for system optimization. The study will be completed and ready to be published by May 30th, 2022.

### Reforestation in encroached farms in forests with a community forestry approach: lessons learnt from the Taungoo district in Myanmar with an emphasis on different tree-planting designs

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Navneet Kumar, University of Bonn, Germany

Lisa Bieber-Freundenberger, University of Bonn, Germany

Christine. B Schmitt, University of Passau, Germany

Agricultural expansions have been a major threat to forest sustainability especially in tropical developing countries. Reforestation in encroached farms using an agroforestry-based community forestry approach has been practiced in Myanmar since 2013 to fulfill livelihood needs and increase environmental sustainability. The study analyzed tree-planting designs found in agroforestry-based community forests on farms and evaluated the performance from a reforestation perspective in the Taungoo district in Myanmar. The study used secondary data, a forest inventory with 44 sample plots (with 400m<sup>2</sup>), and a survey with 291 households. Four categories of reforestation practices were found in the farms which were I) planting trees at farm borders, II) planting trees as forest plots, III) mixing trees with naturally-regenerated trees and IV) the protection of naturally-regenerated trees. The practice (I) showed the poorest performance of 103±65 trees/ha with an average basal area of 1.99m<sup>2</sup>/ha while other practices (II),(III) and (IV) had 767±284trees/ha (3.26m<sup>2</sup>/ha), 1175±464trees/ha (9.31m<sup>2</sup>/ha), and 438±180trees/ha (7.8m<sup>2</sup>/ha) respectively. The main reason for the poor performances was due to farmers’ unwillingness to grow trees near crops as they were concerned about reduced crop production and

income regardless of their socio-economic status. The study highlighted the importance of farmers' awareness of the socio-economic benefits of trees and their motivation to plant trees for successful implementation of reforestation policies.

*Coffee break: 10:00 to 10:30 am*



10:30 am

## Parallel Sessions

Room 200A/B

### Workshop: Farmers' Voices 2

These workshops will be accessible to all delegates and will also be offered free of charge online. They are aimed primarily at people practicing agroforestry around the world and at associations supporting them. Designed and developed in response to questions and concerns shared during satellite events organized on the sidelines of the congress, they aim to provide participants with a space for learning, building knowledge and discussing common agroforestry concerns.

with Juliana Pereira Pino (Brazil), Zénabou Segda (Burkina Faso), Denise Bittencourt Amador (Brazil), Isabelle Tano (Ivory Coast), Alberto Oppata (Brazil), Stéphane Lamanna (Canada), Christian Taillon (Canada) and more.

Languages: English, French & Portuguese

Room 202

### A3. Transitioning to Healthy Soils

Soil recovery of different land-use systems after Mt. Kelud (Indonesia) eruption: Tree-based systems vs monoculture crops

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Rika Ratna Sari, Wageningen University and Research, Netherlands

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Meine van Noordwijk, World Agroforestry - CIFOR-ICRAF, Indonesia

Living on a volcano is dangerous, but has benefits from its extraordinary high soil fertility [1]. However, during the volcanic eruption, soils were exposed to ash depositions which has a direct negative impact on soil. The severity impacts of ash depositions on soils, indeed, depends on the intensity metrics (ash thickness, particle-size distribution) and frequency (return period). However, the vulnerability [2] and subsequent recovery (resilience) [3] of the plant-soil system depends on the land-use system (vegetation and management). We investigated the effects of volcanic ash depositions on soil

properties during short- and medium-term post-eruption recovery phases in four different land-use systems (LUS) of remnant forests, complex agroforestry, simple agroforestry and annual crops. Research plots were established 17 years after the preceding (1990) eruption of Mt. Kelud (Indonesia) and were resampled 3 and 6 years after the 2014 eruption. Each LUS was monitored in three landscape replicates. Data collection included canopy cover, ash and litter thickness, texture, soil organic carbon and carbon stocks, bulk density, macroporosity, aggregate stability and soil infiltration. We found that preserved ash thickness varied between LUS and was strongly affected by the slope position of plots rather than their canopy cover. In the short-term, ash depositions homogenized soil properties across LUS. Variables such as litter thickness, aggregate stability and infiltration rate were changing rapidly after ash depositions, in contrast to soil organic carbon and carbon stocks, texture, bulk density and macroporosity. Surface ash and soil layers showed low aggregate stability and limited water infiltration demonstrating hydrophobicity. However, six years after the eruption, LUS variation resulted in a divergent trajectory of some soil properties. Complex and simple agroforestry recovered more quickly than open-field agriculture in terms of soil carbon stocks and soil infiltration but also received less ash than forests and annual crops systems on other parts of the slope. Keywords: volcanic eruption, resilience, agroforestry, hydrophobicity, soil quality, soil degradation and restoration. References: 1) Sanchez, P.A., Properties and Management of Soils in the Tropics. 2 ed. 2019, Cambridge: Cambridge University Press. 2) Craig, H., et al., Impacts to agriculture and critical infrastructure in Argentina after ashfall from the 2011 eruption of the Cordón Caulle volcanic complex: An assessment of published damage and function thresholds. *Journal of Applied Volcanology*, 2016. 5. 3) Arnalds, O., The Influence of Volcanic Tephra (Ash) on Ecosystems. *Advances in Agronomy*, 2013. 121: p. 331-380.

### Belowground controls in coffee agroforestry systems: soil amendment regimes shape root functional trait expression and fungal communities

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Jacques Avelino, CIRAD, France

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Elias de Melo Virginio Filho, Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica

Marney Isaac, University of Toronto, Canada

Plant resource acquisition strategies reflect a plant's ability to forage and exploit available resources. Belowground, these strategies are coordinated between plant roots and their actively cultivated microbial communities, which is reflected in root functional trait expression that varies along a conservation gradient (from resource acquisition to conservation), and a collaboration gradient (from outsourcing to do-it-yourself strategies). We know that the heterogeneous soil environment largely shapes the expression of root traits and their paired microbial associations, but we have not yet fully explored how the manipulation of the soil environment via specific management practices, including soil amendment regimes, control this plant functioning belowground in biodiverse agroforestry systems. The main objective of this study is to determine how soil amendments shape belowground resource acquisition and microbial collaboration strategies in coffee agroforestry systems. We measured key coffee root functional traits and characterized root endophytic fungal populations under contrasting but widespread soil amendment regimes (inorganic, organic, and organic with additional local soil microbial inoculant). We found that amendment regimes dictate variability in belowground resource strategies. More specifically, coffee plants under inorganic management expressed greater conserving root traits, contrasting plants under organic management with additional local soil microbial inoculant that expressed greater acquisitive roots traits and enhanced collaboration with symbiotic fungi. Interestingly, the local soil microbial inoculant applied to the soil contained relatively minimal symbiotic fungi, but rather mostly moulds and yeasts. Our results highlight that soil amendments differentially control root trait

expression and microbial collaborations, providing further insight into the role of sustainable agroforestry management decisions in shaping plant resource acquisition strategies and foraging capacities.

### Root distribution and characteristics in a young alley-cropping system: potential impacts on soil CNP stocks and enzymatic activity

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\*Christophe Jourdan, CIRAD, France

\*Isabelle Bertrand, INRAE UMR Eco&Sols, France

In alley-cropping systems, the root distributions and traits of annual crops and perennial species in these systems are still unknown even if they directly affect the entries of C in soils. This study aims to link the root distributions and characteristics to soil biotic and abiotic properties according to soil depth and to distance to the tree in a young alley-cropping system. The reduction of root density in the wheat near the UVS especially in topsoils was not due to the soil properties (which were not modified) nor to any presence of perennial roots in the crop zone. The high dissolved organic C found in soil near the UVS could attest the stress of the roots, probably induced by the lack of water observed there. This would also explain the higher lignin content in the wheat near the UVS meant to increase of the absorption capacity. The UVS roots brought a diversity of root traits such as higher root tissue density and ligno-cellulosic index than crop roots. Soil CNP and microbial biomass decreased with depth such as root density. In topsoils, despite a higher entry of organic matter (roots, aerial litter...), the eco-enzyme stoichiometry of the relative C to N vs. C to P acquisition showed higher C needs in topsoils than at depth. In this young alley-cropping system, the root biomass was not increased compared to a hypothetical similar conventional system thanks to the UVS root balancing the loss in wheat near the UVS. The important ligno-cellulosic index in UVS and wheat near UVS roots could lead to a recalcitrance to decomposition and thus increase the potential C storage in AF systems, especially at higher depth, where the CNP needs are more balanced than in topsoils and tends to a stable environment.

### Indigenous peoples, agroforestry and soils: research results of the National Institute for Amazon Research (INPA), Brazil

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\* Robert Pritchard Miller, Instituto Sociedade, População e Natureza, Brazil

Johannes van Leeuwen, Instituto Nacional de Pesquisas da Amazônia, Brazil

Jessica Livio Pedreira, Instituto Sociedade, População e Natureza, Brazil

Rachel Camargo Pinho, Universidade Federal de Roraima, Brazil

Clara Peres Vignoli, Instituto Nacional de Pesquisas da Amazônia, Brazil

Mateus Vieira da Cunha Salim, Instituto Nacional de Pesquisas da Amazônia, Brazil

Ludmilla Gonçalves Verona, Ministério da Agricultura, Pecuária e Abastecimento, Brazil

Fernanda Tunes Villani, Instituto Federal do Amazonas, Brazil

Indigenous agriculture in Amazônia has existed for millennia, with trees as important components. In partnership with indigenous peoples, INPA has been studying these systems, looking at aspects of agrobiodiversity, tree diversity, management practices and soil fertility. Studies in the savannas and forest islands of the Araçá Indigenous Land in Roraima State examined: • Recuperation of soil fertility in a chronosequence of fallows in dry forests; • Soil improvement under



indigenous homegardens in the savannas; • Coppice management of the timber tree (*Centrolobium paraense* Tul – Fabaceae) in fields and fallows; • Soil improvement under “caïçaras” (corrals for cattle) in the savannas.

Other studies were carried out in indigenous lands in Amazonas State: • Microbial carbon, mineral-N and soil nutrients in agroforestry systems and other land use in two indigenous communities in the Upper Solimões River region; • Agrobiodiversity in homegardens in the Kwatá-Laranjal Indigenous Land in Central Amazon; • Soil management in species-rich guarana agroforests (*Paullinia cupana* Kunth) in the Andirá-Marau Indigenous Land, in the Lower Amazon River region. Indigenous agroforestry systems are dynamic, blending ancestral knowledge with new species and techniques. These systems supply food, condiments, medicines, wood for construction and other uses, raw materials for crafts, and in some cases, income, while using little or no external inputs such as fertilizers, liming or chemicals. Soil fertility is improved and maintained through processes such as fire management, fallows, efficient nutrient cycling by trees, and in the case of homegardens, inputs of nutrients from domestic residues and manures. With the ecosystem services provided by Amazonia increasingly threatened by deforestation and conversion of forests to pastures and monocultures, indigenous agricultural system offer lessons as to alternative possibilities for more sustainable use of soils and biodiversity.

Farmers' Representative in this session: Rafael Pompa, United Kingdom

Room 301A

## B2. Transitioning to Better Water Balance and Light Valorization

Water-use efficiency of *Populus deltoides* × *P. nigra* in mixed forest and agroforestry plantations

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\*Nicolas Marron, Université de Lorraine, AgroParisTech, INRAE, UMR Silva, France

Damien Bonal, Université de Lorraine, France

Séverine Piutti, Université de Lorraine - INRAE, France

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In the global context where water will become a scarce resource under temperate latitudes, managing both forest and agroforestry plantations with mixed species could play a major role to optimize the use of this resource. Conceptual frameworks in community ecology indeed suggest that, in mixed plantations, environmental resources such as water may be more efficiently captured and used because of niche complementarity among species. Such positive effects in species diverse plantations have been seldom demonstrated. To test these hypotheses, water-use efficiency (WUE) was estimated for poplar trees grown in monoculture, or in association with alder trees (forest mixture), or in association with clover crop (agroforestry) in an experimental plantation located in northeastern France. The experience focused on the 7th growing season in 2020. WUE was estimated at tree level with sap flow sensors, at wood level with carbon isotope composition, and at leaf level with both gas exchange measurements and carbon isotope composition. Poplar trees in both mixture types were more efficient to use water compared to those in monoculture. The different methods used to estimate WUE gave consistent information. Differences in WUE between monoculture and agroforestry were explained by differences in leaf level stomatal conductance or tree level transpiration, while on the contrary, differences between monoculture and forest

mixture were due to differences in carbon assimilation and biomass accumulation. Moreover, the more WUE was integrated in time, the more the differences among treatments were marked (instantaneous gas exchanges < leaf life span < seasonal wood core < whole tree). From an agronomic perspective, higher biomass production, as we have already been able to demonstrate within this plantation (1), associated with less water consumption when poplar is grown in association with a leguminous crop makes this kind of cultural system very promising in the climate change context. (1)Thomas, A., Priault, P., Piutti, S., Dallé, E., Marron, N., 2021. Growth dynamics of fast-growing tree species in mixed forestry and agroforestry plantations. *Forest Ecol Manag* 480, 118672. <https://doi.org/10.1016/j.foreco.2020.118672>

### Species interactions dynamics in fast growing poplar and alder forestry and agroforestry systems: from leaf to tree

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In recent years, plantations of fast-growing tree species have emerged as a possible way to meet the increasing demand for biomass for renewable energy in Europe. Agroforestry plantations including fast-growing tree species could be an attractive option because they reduce land competition for biomass and food production while providing forest benefits. Today, the species interactions that determine whether a given mixture will be more productive than the corresponding monocultures are still poorly understood. Our objective was to assess the performance of fast-growing poplar and alder trees in an experimental plantation set up in 2014 including different treatments, i.e. poplar and alder (1) in monocultures, (2) in association together (forest mixture) or (3) in association with herbaceous species (agroforestry) either N<sub>2</sub>-fixing species (succession alfalfa and clover) or graminoids (succession of wheat, triticale and temporary grassland) respectively. During eight growing seasons, tree growth was monitored monthly, while leaf (eco)physiological traits (e.g. photosynthetic capacities) were investigated since 2017. During the early stages, negative interspecific competition between crops and poplars predominated and required management actions. A facilitation process in the poplar agroforestry treatment, due to a significant enrichment in soil nitrogen by the N<sub>2</sub>-fixing crops, led to a higher stem height in agroforestry poplars than in the forest mixture and the monoculture at the end of the 6th growing season\*. For alders, tree growth did not appear to be affected by either an association with graminoids or with poplar. No overall significant treatment effect was observed on leaf traits but intra-annual dynamics revealed different tree responses to specific seasonal conditions, with for instance agroforestry poplars maintaining higher growth rates and photosynthetic performances during the 2018 summer drought compared to poplars in forest treatments. This could highlight a better acclimation capacity to potential constraining conditions for poplars in agroforestry stands.

### Agroforestry trees start to develop deep fine roots from 5 years of intercropping

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It was reported that intercropped trees in alley-cropping agroforestry systems develop deeper fine roots compared to forest trees but its initialization during the young age of trees remains poorly studied. The aim of this study was to count tree fine

roots abundance along a chronosequence of agroforestry stands and to determine factors explaining its variability. Seventeen alley-cropping plots with ages ranging from 3 to 12 years old were chosen in farmers from northern France. Tree fine roots abundance (TFRA) were measured with core-break method. Soil cores down to 2 m depth were collected at 0, 1, 3 and 10 m from a referent tree on both sides of the tree row. The variability of TFRA was analysed with soil, plant and stand parameters as well as crop management practices. During the first four years of plantation, trees developed abundant fine roots in 0-30 cm depth along rows. Then, between 4 and 6 years old, they started to expand deep roots (1-2 m depth) first in tree rows (Figure 1B). Beyond 6 years old, TFRA was high in 1-2 m depth out of tree rows, testifying the lateral expansion. The total TFRA was significantly different between tree species ( $R^2 = 0.2^{***}$ ): low, intermediate and high for hornbeam, hybrid walnut and maple respectively. It was positively correlated with tree age ( $R^2 = 0.3^{***}$ ), soil tillage ( $R^2 = 0.4^{***}$ ) and crop fertilization ( $R^2 = 0.2^{***}$ ). When data from tree rows were excluded, stepwise analysis showed that the variability of TFRA in 1-2 m depth was explained at 78% by tree age, tillage frequency, rotation duration, crop yield and soil sand content. We conclude that the change in tree fine roots growth strategy starting at 5 years old is a key period to well manage tree/crop competition in AF systems.

### Conversion of forest to silvopasture versus open pasture in the northeastern U.S.: Implications for ecosystem service synergies and trade-offs

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Silvopasture is a promising agroforestry system that may support climate adaptation and mitigation, land use diversification, consumer demand for local products, and building socioecological resilience in the northeastern U.S. However, our understanding of silvopasture's potential to sustainably produce a range of ecosystem services—and the tradeoffs and synergies among different ecosystem services—remains poor. The objectives of this study were to (1) assess the effects of forest-to-pasture and forest-to-silvopasture conversion on diverse ecosystem services (e.g., hydrologic regulation, carbon storage, soil greenhouse gas fluxes, nutrient losses, and microclimate amelioration), and (2) explore the potential tradeoffs and synergies among these services. The study design consisted of an experimental manipulation with three treatments (forest-to-pasture conversion, forest-to-silvopasture conversion, reference forest) implemented at two field sites (southeastern NH and upstate NY). Data on evapotranspiration (sap flow, throughfall), saturated hydraulic conductivity (well permeameter), tree biomass and productivity (allometry, dendrochronology), soil carbon and nitrogen (concentrations and stocks), soil greenhouse gas fluxes (instantaneous and seasonal CO<sub>2</sub> N<sub>2</sub>O) and microclimate were collected over four years. We observed that during a drought year (2016), *Pinus strobus* in the silvopasture used more water compared to *P. strobus* in the reference forest, while *Quercus rubra* in silvopasture maintained higher radial growth, suggesting enhanced resilience to climate extremes in silvopastures. Results also suggest enhanced hydrologic regulation under silvopasture compared to open pasture due to lower soil bulk density, greater soil hydraulic conductivity, and increased evapotranspiration. Soil CO<sub>2</sub> fluxes were higher in the open pastures compared to silvopasture and reference forest sites. Soil N stocks and soil N<sub>2</sub>O

fluxes followed similar trends as soil CO<sub>2</sub>. These findings are used to explore potential tradeoffs and synergies among different ecosystem services. Combined, our results suggest that silvopasture may offer an intermediate land use system that supports the expansion of food production while sustaining multiple ecosystem services.

### Nonlinear buffer design: evaluating the AgBufferBuilder tool

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Field-edge and riparian forest buffers are established agroforestry practices which provide wildlife habitat and forest crop production opportunities and improve water quality. In the U.S., implementation of forest buffers depends largely on voluntary adoption by landowners balancing crop yields with water quality and habitat benefits. This project examines potential improvements in buffer performance through targeted non-linear buffer placement. AgBufferBuilder, a buffer design tool developed by the United States Forest Service (USFS) National Agroforestry Center, designs targeted buffers at field scale using DEM-based flow analysis and soil factors. Our study objective is to test AgBufferBuilder's value as a design tool across several land-use contexts. Three HUC-12 watersheds within the Shiawassee basin of Michigan's Saginaw Bay watershed were selected as our study area, representing high, medium, and low estimated sediment contributions based on the Great Lakes Watershed Monitoring System (GLWMS) tool. Selected areas of interest (AOI) are modeled using AgBufferBuilder. Soil type is determined for each AOI from the USGS Web Soil Survey. AgBufferBuilder is set to model buffers capturing 75% of total AOI sediment runoff. Preliminary results show designed buffers for high, medium, and low sediment-loading HUC-12s represent average increases of 90.7%, 83.1%, and 67.5% in the total amount of sediment captured compared to existing practices while using an average 4.3%, 1.8%, and 3.8% of the total AOI, respectively, compared to an average 7.1%, 11.4%, and 23.7% of AOI currently not in crop production. Ongoing work will refine tool-designed buffer designs to accommodate tractor movement while preserving the entire AgBufferBuilder design. Final designs will show existing, proposed, and overlapping tool-generated buffer areas and simulated final designs incorporating tractor movement. Final analysis will quantify the existing crop production area transitioned to buffer and model crop yields and harvest rates under multiple scenarios to better inform buffer implementation and supporting programs.

Room 304A/B

## D5. Transitioning to a Viable Climate

How much can agroforestry, including hedgerows, contribute to the net zero emission target in the UK?

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Territorial annual greenhouse gas (GHG) emissions in the UK have reduced from 809 Mt CO<sub>2</sub>eq in 1990 to 454 Mt CO<sub>2</sub>e in 2019 (1). The target is reach net zero emissions by 2050. During the past 30-years, annual GHG emissions from UK agriculture, forestry and fisheries have declined from 54.6 to 47.3 Mt CO<sub>2</sub>e, but the proportional contribution to emissions has increased from 6.7% to 10.4% of emissions. About 84% of the agriculture-related emissions were in the form of either

methane (24.9 Mt CO<sub>2</sub>e) or nitrous oxide (14.8 Mt CO<sub>2</sub>e) (1). The increased carbon sequestration of woodland, including substantial new areas planted in the 1970s and 1980s, and other forms of land use and land use change (LULUC) has led to a reduction in LULUC and forestry emissions from 18.0 Mt CO<sub>2</sub>e in 1990 to 5.9 Mt CO<sub>2</sub>e in 2020 (1). The UK Government has reported that agroforestry, including hedgerows, in the UK could result in carbon emissions savings of 5.9 Mt CO<sub>2</sub>e per year by 2050 (2), i.e., about 12% of current agriculture-related emissions. As part of a “balanced net-zero pathway” to zero-emissions, the UK Committee on Climate Change Plan has outlined the need to increase woodland and tree cover in the UK from 13% to 18% and to increase the annual removal of GHGs by land-based carbon sinks from 18 Mt CO<sub>2</sub>e in 2019 to 39 Mt CO<sub>2</sub>e by 2050 (3). Between December 2021 and February 2022, Cranfield University is undertaking a detailed desk study to determine the validity of above targets for agroforestry to reduce net greenhouse gas emissions with a focus on England. The study is reviewing the potential of three types of agroforestry (silvopastoral, silvoarable, and hedgerows) to sequester carbon and reduce greenhouse gas emissions, and the potential economic benefits. This paper will report on the results and discuss the implications of the findings and an updated abstract will be provided in February 2022. 1. Department for Business, Energy and Industrial Strategy (2021). Final UK greenhouse gas emissions national statistics June 2021. <https://data.gov.uk/dataset/9568363e-57e5-4c33-9e00-31dc528fcc5a/final-uk-greenhouse-gas-emissions-national-statistics>. 2. UK Government (2020) Guidance: Agroforestry and the Basic Payment Scheme. <https://www.gov.uk/guidance/agroforestry-and-the-basic-payment-scheme>. 3. Committee on Climate Change (CCC) (2020). The Sixth Carbon Budget. The UK's path to Net Zero. December 2020. <https://www.theccc.org.uk/publication/sixth-carbon-budget/>

### Carbon balance components of a black locust-based agroforestry site under Mediterranean climate

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Agroforestry systems (AFS) can provide many services, among which sequestering atmospheric carbon (C) dioxide (CO<sub>2</sub>) into both tree biomass and soil organic matter for mitigating climate warming. Such high performances were documented in several studies, but data are still scarce for covering the broad range of agrosystems – climate combinations. More particularly, data of the different C stocks and fluxes among the different components of the AFS needs to be documented for robust estimates of C sink strength. This study aims at providing values of C stocks and fluxes of a black locust (*Robinia pseudoacacia* L.)-based agroforestry site in Mauguio, Southern France. The different compartments of the AFS were investigated: the black locust rows, the herbaceous strip planted of various grassland species along the trees and the intercropping, constituted by a rotation cereals/legumes. The crop rotations comprised durum wheat, barley, chickpea and pea, but we presented the data for the barley planting year in 2021. A forest plantation and a pure crop planting systems were also studied as control modalities. The three planting systems were repeated in three independent blocks. Aboveground tree biomass growth was estimated for the agroforestry and the forestry plots from allometric models. Black locust litter fall was quantified also in the agroforestry and forestry plots. For each planting systems, root biomasses, root C

contents and root growth were estimated. Aboveground herbaceous biomasses and C contents were also measured in 1m<sup>2</sup> squared plots at different seasons. Soil microbial biomass and soil CO<sub>2</sub> efflux were measured in all components and planting systems. All data currently under processing will be normalized per area unit. The effect of the planting system was assessed in order to determine the added value of the agroforestry system with respect to the pure planting systems.

### DigitAF, a European project to help agroforestry meet climate, biodiversity and farming sustainability goals: linking field and cloud

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In this presentation, we will summarize a recently accepted Horizon Europe project called “DigitAF: DIGItal Tools to help AgroForestry meet climate, biodiversity and farming sustainability goals: linking field and cloud”. The overall aim of the four-year project is to scale up and boost agroforestry in the EU by defining the right conditions for its high-quality implementation. The project will enable this by developing digital tools tailored to the needs of key stakeholder groups whose decisions impact agroforestry implementation. Thus, DigitAF will: (1) Help policy actors design policies better suited to encourage the adoption of agroforestry and carbon farming (2) Provide tools that help practitioners manage the complexity of agroforestry systems, letting them optimize the design and management of agroforestry systems, at field and farm scale (3) boost the capacities of key actors along the value chain to assess, quantify and market the economic, environmental and social performance and benefits of agroforestry. DigitAF will follow a multi-actor approach centred on end-users (Fig 1), made possible by implementing six living labs in Italy, Germany, the Netherlands, the United Kingdom, Finland, and the Czech Republic. Open-source tools, based on existing and novel practical knowledge, scientific evidence and models, will be developed and submitted for feedback to living lab actors. The project is about to start, and we invite fellow researchers, agroforestry practitioners, policy-makers, modellers, food processors, marketers, and others to join us in this adventure. Together, let’s co-develop tools that will address the key economic, environmental, and social needs of our time.

### Effect of temperate silvoarable systems on temperature and moisture regime influencing biomass and photosynthetic activity

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Large land blocks resulting from the socio-political changes after WWII in Central Europe show little resilience to (among others) long periods of drought. Having insufficient knowledge so far, we aim to bring more light into complexity of temperature and moisture regimes of agroforestry systems (AF) under specific temperate conditions. The effects of trees were studied at two localities with similar ecological conditions, but with different types of agroforestry systems: (i) Pr'honice: 15 m between dense tree lines (17 years) and narrow grass belts; (ii) Šardice: wide grassland belts (13m), 10 years, large plant spacing, 60-80 m between belts. Both localities were equipped with soil temperature and moisture sensors. Flights of drone (MicaSense Altum) were performed during seasons 2020 and 2021. The NDVI and NDRE indices and surface temperatures were evaluated in respect to several (non-)shaded variants of AF and full-sun plot. NDVI and NDRE were identical during crop growth (2020) for "full-sun" and "AF-shaded-crop" whereas AF-trees and AF-sunny showed statistically significantly lower values. Surface temperatures are the lowest in shaded crop (by 2°C on average). We recorded better qualitative parameters of wheat grains coming from the most shaded areas during the season. Ground data revealed different patterns of soil moisture in topsoil and subsoil. In subsoil, the humidity under trees decreases probably due to water uptake by trees, while the highest humidity show full sun plots. The trends in topsoil differed in two seasons for full sun plots, probably due to varying precipitations. We conclude that AF can effectively mitigate negative effects of droughts despite certain competition for water. In this respect, smaller spacing between tree lines with narrow grass belts is more suitable. The photosynthetic activity is comparable for AF-shaded-crop and full-sun, being dependent also on air humidity. The higher quality of agricultural products has a potential to compensate lower yields in AF.

Room 303A

### G3. Transitioning to a Viable Society

Catalyzing Appalachian Agroforestry: One Institution's Experience Coordinating 20+ Years of Decentralized Partnerships, Progress, and Practice

\*John Munsell, Virginia Polytechnic Institute and State University, United States

John Fike, Virginia Polytechnic Institute and State University, United States

Appalachia is a 1.91 million square kilometer physiographic region located in the eastern half of the United States of America. The iconic landscape encompasses 13 states, from New York to Alabama. Ridges and valleys, highlands, plateaus, hills and hollows, and undulating topography are defining features, as are forests and fields, creeks and rivers, and rich biodiversity. It is one of the oldest mountainous regions in the world. Unfortunately, it is also known for high rates of economic distress and environmental exploitation tied to extractive land uses such as coal mining. Agroforestry is part of an ongoing regional reinvestment strategy designed to leverage Appalachia's natural resources in ways that enhances community wealth and sustains environmental health. Virginia Polytechnic Institute and State University (Virginia Tech) is located in Central Appalachia and has long been a hub of decentralized agroforestry partnerships that seek to achieve regional reinvestment goals. The university's agroforestry portfolio includes publicly and privately funded partnerships involving higher education institutions, state and federal agency employees, non-profit organizations, timber and non-



timber dependent industries, agricultural companies and associations, and large networks of experienced and new producers. This presentation traces the history of Virginia Tech's role in catalyzing Appalachian agroforestry using diverse decentralized partnerships. The objective is to share successes and lessons learned with regional agroforestry partnerships the world over. The emergence of diverse collaborations at Virginia Tech more than 20 years ago are covered. Decentralized models for success using examples from previous and ongoing funded research and outreach projects are presented, as well as associated increases in adoption, demand for Appalachian agroforestry products, and producer and community benefits. Examples of independent partner accomplishments also are shared. Arguments are made in conclusion that decentralized rather than centralized strategies are best for catalyzing agroforestry due to necessary heterogeneity and creativity of application.

### Planning beyond the plot: optimizing the integration of agroforestry intercropping systems in temperate agricultural landscapes

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Alain Olivier, Université Laval, Canada

Agroforestry intercropping systems (AIS), also known as tree-based intercropping (TBI) systems, consist in woody perennials integrated within agricultural plots in largely spaced rows. The contribution of AIS to the construction of sustainable landscapes could be enhanced by using a landscape approach that would ensure that their design optimize not only their adaptation to the farm context, but also their impacts and the provision of ecosystem services at the landscape level. Since no decision-making tool is readily available to guide the implementation of AIS systems in such a perspective, and considering that the range of woody species recommended in these systems could be broaden, we developed two decision-guiding tools adapted to Quebec's agricultural landscape contexts based on a literature review of the ecosystem services provided by AIS in temperate contexts, interviews with agroforestry experts, and several guides and tools describing woody species. The first tool is a multi-criteria grid presenting criteria and thresholds aimed at guiding the choice of AIS implementation site and design features (row spacing, tree orientation, woody species characteristics, etc.) to address seven challenges facing agricultural landscapes: water and soil conservation, air quality, carbon sequestration, habitat fragmentation, landscape aesthetics and rural economic vitality, each criterion being associated to one or more challenges. The second tool presents 28 woody species that could be potentially useful in AIS, each one described upon 23 criteria covering morphological, ecological, landscape aesthetics and economic features. The combination of these two tools demonstrates that AIS can be adapted to a wide variety of agricultural contexts, and that the choices of AIS features can be optimized to enhance the provision of ecosystem services while ensuring their adaptation to the farm conditions. Embracing the growing movement toward a reappropriation of the agricultural landscape by its inhabitants, our tools are expected to foster AIS deployment in rural territories and their contribution to the construction of viable, rural landscapes.

### Exploring the re-usability of serious games to support management of complex (agro)forested landscapes; the case of the RESORTES board game

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Background: “Serious gaming” has emerged as a highly innovative participatory approach to explore adaptive landscape-level decision-making in which games function as (social) learning tools and boundary objects. While this approach is increasingly popular and ever more success stories are published, critics question the high development and implementation costs and the relative low numbers of participants reached associated to the often seen “one-study-one-game” approach. Objectives: We aimed to address some of the critiques to the serious gaming approach by exploring the re-usability of games. Methods: We explored the re-usability of the RESORTES board game, originally developed for a landscape in Mexico. The RESORTES game is a closed and realistic land-use decision-making game that depicts a tropical (agro)forested landscape and captures some of the current challenges in these complex landscapes. We applied the game in a landscape in Nicaragua and a landscape in Indonesia. We assessed the need for and ease of making game adjustments and similarities in game dynamics. Results: In both the Nicaraguan and the Indonesian case study, few simple adjustments to the game were made. These minor adjustments were made to provide a better link to the local context. In both cases, participants in game sessions, easily engaged through the game. Similar decision-making processes were seen between game sessions in Mexico, Nicaragua and Indonesia. Discussion: RESORTES facilitated in-depth land-use discussions among participants. The generic nature of the board game facilitated simple adaptations and it allowed participants in all three landscapes to easily transpose their contexts into the game and have meaningful discussions. Conclusion: This study showed that re-using games is an interesting option to reduce high development and implementation costs of games, while also increasing the number of participants per game. In addition, it allows for comparative analysis on decision-making processes in complex (agro)forested landscapes.

### Serious Game Simulation for Promoting Agroforestry in the Recharge Area of Rejoso Watershed, East Java, Indonesia

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Background: Economic growth has in many countries led to hydrological degradation. Efforts to restore hydrological functions face economic pressures and insufficient understanding of socio-ecohydrological systems. Knowledge transfer among stakeholders is limited. The Rejoso Watershed (1600 km<sup>2</sup>) on the slopes of the Mount Bromo volcano supplies water to the Umbulan Spring. Through a national project, the spring provides drinking water to 1.3 million people in Surabaya. However, the discharge of Umbulan has decreased significantly in the last 20 years because (1) intensive agriculture in the recharge area (upstream and midstream) and (2) groundwater exploitation through massive artesian wells in downstream. Objectives: Knowledge transfer and communication among stakeholders, including incentives for agroforestry in the recharge area and control of artesian wells in the downstream area. Methods: We developed a serious game that imitates the actual condition so people can test various strategies to achieve their targets, without neglecting the basic elements of gaming (e.g., challenges, rewards, experiences, strategies, emotions). Through the game programs proposed by the watershed forum to address the issues are tested: We invited farmer groups from the upstream, midstream and downstream areas to join and play. During the simulation, the land management decisions and cooperation among zones were recorded. Results: Farmer groups with previous exposure to and participation in conservation programs were more

willing to shift to agroforestry land use. However, they demand the downstream farmers to coinvest in conservation actions. Lowland farms that substitute rice for fruit production saved water and did well. Discussion: Visualizing groundwater flows and flooding risk provided new understanding to participants and led to social interactions among the zones that don't yet happen in the real world. Conclusion: This game allows participants to see the entire watershed as one hydrological system and to realize that land-use decisions affect hydrological function, with social consequences.

### Plot-level scenario games for sustainable agroforestry management: Farmer choices facing risks in Kali Konto sub-watershed, Indonesia

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Background: Trade-offs between economic and ecological aspects of land use sustainability are hard to manage in uncertain climates and markets. Farmers make choices using experience, current (incomplete) information and social influences. Rather than imposing normative economic or ecological rationales for farmer choices, games can help to a) understand farmer choices in a given economic and ecological context, b) offer learning opportunities, and c) trigger collective responses. However, a game-design tradeoff between abstract generic and locally fine-tuned specific games is unresolved. Objectives: We aimed to test a newly developed game for applicability, insights on differentiated farmers' land management choices, farmers' learning curves and collective action. Methods: Our 3D board game represents plot-level choices with financial cost and benefits, but also links to ecological impacts on litter, water balance, and erosion. The Q methodology was applied before and after game session to measure the impact on discourse change in sixteen pilot individual sessions in the Kali Konto smallholder agroforestry mosaic landscape. Results: Older farmers tended to choose agroforestry systems with lower risk and inputs cost and more flexible time management, while young farmers preferred annual crops to obtain higher income to fulfil higher family expenses, accepting the associated risks. Game results also indicated differences between males and females in plot management and spatial pattern. Where market access was identified as dominating farmer land management, ecological and socio-economic reasons became more prominent after a game session. Discussion: the game accommodated a self-learning process which modifying explanatory discourse. Neighbors choices influence decisions, as part of social decision making. Diversifying options that overcome socio-economic pressures might shift management choice from monoculture to mixed system, considering (younger) farmers could response better to new information/intervention. Conclusion: as step towards a landscape-level interaction game, the plot-level game invokes engagement and identifies age and gender differentiation of farmer preferences.

Room 301B

## I2. Transitioning to Viable Policies

Agroforestry Policy in the US needs an accelerator - and Canada's needs a lifeline

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\*Margaret Gullion, Faculty of Forestry, University of British Columbia, Canada

Terry Sunderland, University of British Columbia, Canada

Agroforestry is an old land use that has been practiced by people around the world for thousands of years, and modern research has shown that it can be effective in improving food security, diversifying income, and providing a host of ecosystem services, including in temperate climates. Despite this potential, agroforestry remains under-employed in the US and Canada, and requires policy support for scalable adoption. The US and Canada share important climatic, cultural and economic contexts for agroforestry, while operating in specific political and policy frameworks. We conduct a comparative analysis of Canadian and American agroforestry in two ways: first, through an analysis of Canadian and US agroforestry policies; and second through an analysis of active Canadian and US agroforestry (or agroforestry adjacent) groups and organizations. We find that while US agroforestry policy is far from perfect, the USDA Agroforestry Strategic Framework and accompanying federal programs provide steady, long-term institutional and financial support for many agroforestry practices while equivalent Canadian government institutions and funding are absent - or only present in short term or localized contexts. Canada can emulate successful aspects of US agroforestry policy by institution long-term, federal strategic initiatives and funding. Both countries can improve the effectiveness of their programs by 1) increasing agroforestry knowledge creation and translation; 2) ramping up funding for well-designed incentive and support programs; and 3) capacity building and integration across sectors. Sustainable transitions to agroforestry land uses can be profitable, and environmentally & nutritionally beneficial, but pro-active policies are required to catalyze this transition on a larger scale in the US and Canada. An informed and cooperative agroforestry policy approach between these two close neighbours is an important step towards sustainable food security in North America.

Information needs and communication channels for wider agroforestry adoption in the U.S.

\*Olga Romanova, University of Missouri, United States

\*Michael Gold, University of Missouri, United States

Damon Hall, University of Missouri, United States

Mary Hendrickson, University of Missouri, United States

On-the-ground adoption of U.S. agroforestry remains limited despite its' recognized potential to provide a broad range of economic, ecological, and social benefits. In the U.S. about 1.5% of farms self-identified as practicing one or more agroforestry practices. Information dissemination is key for raising interest and involving more potential agroforestry adopters, however, different groups of farmers require different message constructs and utilize different channels of communication. Thus, identifying current agroforestry practitioners' needs in information, preferred channels of communication, and experience of adoption can help to construct efficient messaging and deliver it through effective channels to a wider group of potential adopters. Studies involving active agroforestry practitioners are limited and are the focus of this research. The perspective of early adopters who have implemented agroforestry projects with the support of U.S. federal funding has been assessed through analysis of their project documents and reports (n=85), survey (n=37), and interview (n=15). Lack of locally specific information and demonstration farms, lack of expertise and guidance for

establishing agroforestry practices, and lack of shared knowledge were found to be limiting agroforestry adoption. While strengthening networks, developing agroforestry extension programs, and increasing financial support can improve the informational and institutional support system. Other key findings: (1) indirect mass and direct interpersonal communication both work as an initial source to learn about agroforestry, but direct interpersonal channels are more efficient for the decision to adopt; (2) agroforestry practitioners become essential contacts and sources of trustworthy information for others given that practices, projects, and approaches are often unique to their respective regions; (3) even in digital age printed publications are still highly appreciated. Recognizing the kind of support required for AFP initiation and long-term continuity and utilizing efficient channels of communication to reach target groups of farmers should help to advance AF adoption in the U.S.

### Silvoarable policy promotion in the Mediterranean EU

Francisco Javier Rodríguez-Rigueiro, University of Santiago de Compostela (USC), Spain

José Javier Santiago Freijanes, University of Santiago de Compostela, Spain

Nuria Ferreiro-Domínguez, University of Santiago de Compostela, Spain

\*María Rosa Mosquera-Losada, University of Santiago de Compostela (USC), Spain

Climate change influences all the European regions and jeopardizes rural economy and food supply. The European Commission is leading European Policies towards a more resilient ecosystem including adaptation and mitigation measures as a centrepiece on its strategy, drawn by legislation adaptation to the UN Agenda 2030 through the EU Green Deal. Silvoarable systems are key tools that provide multiple ecosystem benefits potentially contributing to reach the proposed objectives. This study aims to analyze EU policy promotion of silvoarable systems through the Rural Development Programmes (RDPs) of the Common Agricultural Policy (CAP). This policy analysis was performed employing the “Land use/cover area frame statistical survey” (LUCAS) and the study of the measures incorporated in the Pillar II of the CAP 2014-2020 by 27 EU Member States, all but Greece and Cyprus, promoting practices where widely spaced woody vegetation is inter-cropped with annual or perennial crops. According to the analysis, the Mediterranean regions of the EU promote silvoarable practices in 22 RDPs (Fig 1), while five regions from Spain (Valencia, Aragón, Baleares, La Rioja) and Italy (Sardinia) do not provide support. Portugal and the Italian region of Molise are the EU Mediterranean regions providing higher support with up to four measures, followed by the Spanish region of Andalusia with three. Sicilia, Basilicata, Campania, Lazio and Umbria regions in Italy, and Provence-Alpes-Côte d’Azur in France, incorporate two measures. One measure supporting silvoarable practices is included in the remaining Spanish and Italian regions, and Languedoc-Roussillon and Corsica in France. The maintenance and establishment of these measures is key in areas like Portugal and Andalusia, where mixed farming systems and feed to livestock from woody vegetation preserve farms profitability and rural economy. Furthermore, the positive effect of silvoarable systems on soil conservation and capitalization through nutrient recycling, biodiversity promotion and water preservation make it crucial to fulfil EU Green Deal goals. In conclusion, it can be observed a shortage of RDPs measures supporting silvoarable systems in most of the regions, leading to a huge potential to cope with climate change mitigation and adaptation through silvoarable practices promotion.

Farmers’ Representative in this session: Justice Zvaita, Zimbabwe

Room 204A

## N2. Which Agroforestry for an Edible Food Forest?

Traditional, tree-dominant agriculture reverses forest loss in watersheds

\*Kamal Melvani, Neo Synthesis Research Centre, Sri Lanka

Moles Jerry, NEO SYNTHESIS RESEARCH CENTRE, Sri Lanka

Forest destruction in populous tropical countries is mainly caused by agricultural expansion and results in decreased forest ecosystem services and livelihood impoverishment. For example, 100 years ago, forests in the Maragala Oya (river) watershed in Sri Lanka's Intermediate agroecological zone (1750-2500mm) were cleared for traditional swidden (fire-fallow) cultivation and plantations. With increasing population pressure, farmers continued to cultivate but did not fallow land. Land degradation ensued with decreased watershed productivity, increased habitat loss, and impoverished livelihoods. Alternately, if traditional, tree-dominant agriculture or forest gardens (FGs) were adopted, this could reverse forest loss, improve watershed productivity and increase livelihood security. The Neo Synthesis Research Centre demonstrated this in Jane Nona's landholding (JNL) interspersed between forest remnants on the landscape mosaic. Preliminary discussions revealed household issues, needs and available resources. Baseline surveys assessed topography, light, wind and water flows, vegetation structure, composition and ecological functions, and faunal species in JNL, forest remnants, and surrounding land uses including streams. This information guided the rehabilitation of JNL into FGs utilising multiple tools including analog forestry. 5000+ diverse plants were established between 1999-2004. Short-term monitoring occurred annually, including mapping of plants established and measuring increases in shade, topsoil, leaf litter, surface, soil and aquatic biodiversity. Income data (including household consumption) were collected weekly. Long-term outcomes were evaluated by comparing bird diversity between Jane's FG and adjacent natural forests; and assessing Jane's social, ecological and financial values for FGs and other land uses in her landholding. Ten years later (2012-2013), Jane's multi-strata FG became the biodiversity corridor between forest remnants, had greater shade, soil organic matter and moisture, and recharged aquifers. Average annual income increased from \$54 in 1999 to \$26,000 in 2014, of which 96% was from sales and 4% household consumption value. Jane's prosperity motivated other farmers in the watershed to rehabilitate their landholdings.

Adoption of agroforestry practices in private forests: experiences and perceptions of landowners in Quebec

\*Maxime Saulnier, Université Laval, Canada

Maude Flamand-Hubert, Université Laval, Canada

David Rivest, Université du Québec en Outaouais, Canada

Despite agroforestry's recognized benefits, this mean of production remain marginal in Québec and even more so in its forested environments. Although agroforests and domestic forests are agroforestry's forested side, there is no specifically dedicated State support offered to private forest owners for their management. In this context, it appeared relevant to study the realities lived by private forest owners practicing agroforestry in their forest in spite of the absence of public policies taking those practices into account. This presentation will share the results of a project research who aim to document the agroforestry practices of private forest owners and the obstacles they face; to understand their motivations, their behaviors and their perceptions; and also to identify their needs and interests. In advocating for a qualitative approach, this multicase study conducted walking interviews with seven private forest owners as well as six individual semi-structured

interviews with Québec's agroforestry key players. This method enabled us to document in depth private forest owners agroforestry practices, to clarify their needs and their interests as well as to better understand their realities, their environments and their experiences of agroforestry. Furthermore, results highlighted private forest owners reference figures and archetypes that will allow propositions and institutional solutions to be formulated in order to promote the development of agroforestry in forested areas. Using those archetypes as a starting block and based on the domestic forests concept, a conceptual schema unique to agroforestry in Québec's private forests can now be elaborated.

### Investigating the specificity of ectomycorrhizal fungi: A first step towards mycoforestry in eastern Quebec

\*Simon Bessette, Université Laval, Canada

Jean Bérubé, Canadian Forest Service, Natural Resources Canada, Canada

Stephanie Beauseigle, Biopterre, Canada

Louis Bernier, Université Laval, Canada

Mushroom harvesting is gaining popularity as an opportunity for economic diversification in the forest industry. Reliable data on the ecological dynamics of ectomycorrhizal (EM) fungi are needed to develop a new forestry model called mycoforestry (also known as mycosilviculture) which integrates this resource into forest management. The aim of this collaborative study is to qualify the symbiotic specificity of one of the most promising edible EM fungi for mycoforestry in the northern temperate forests of eastern Quebec. The objectives, protocol, and schedule were developed jointly by the Laval University and government research team, bioproduct development centre Biopterre, and Réseau Forêt-Bois-Matériaux, an organization whose mission is to coordinate and support the local forest industry. During the summer of 2021, EM fungi of interest to the agri-food industry were identified in the Témiscouata area of eastern Quebec. Soil samples were taken from some of the sites to collect roots colonized by EM fungi. The fungal species colonizing each root have been identified through metabarcoding using the Illumina platform. The most frequent species of interest will be targeted in the second phase in the summer of 2022. The soil of previously identified sites will be sampled in the same manner as the previous summer. This time, plant species will also be identified through metabarcoding. Data from the sequencing will allow us to identify precisely which tree species are more frequently associated with the targeted fungal species. This study will provide valuable data for the development of mycoforestry as it will enable forestry managers to select the tree species that will promote the growth of targeted fungi.

Farmers' Representatives in this session: Jograj Giri, Nepal & Yvan Perrault, Canada



Room 204B

### Side Event: Smallholder Agroforestry Through Tech-Enabled Carbon Payments

Rabobank's ACORN unlocks access for smallholder agroforestry farmers in developing countries to the voluntary carbon market and insetting structures. ACORN uses remote sensing and innovative scalable certification and verification protocols to ensure full transparency on the carbon sequestered. For each 1000 kg of carbon sequestered, a minimum price of €20 is charged, of which 80% goes straight to the farmer. Do you want to know how ACORN does this? Join the team for an interactive workshop, diving deep into the innovations in carbon markets, payments for ecosystem services and the potential revenue streams agroforestry can generate for smallholders worldwide.

by Emma van de Ven and Max Berkelmans from Rabobank

Language: English

Room 203

### Side Event: Take a break: Play to understand the benefits and constraints of agroforestry

Should I plant trees? Should I cut them down to collect wood? Is it better to convert my fallow land to grain, pasture or coffee? Workshop participants will put themselves in the shoes of a farmer who must make decisions based on various contextual and individual constraints and opportunities. The serious games presented in the workshop were developed with stakeholders (farmers, support services, government officials, etc.) following the Companion Modeling approach (ComMod). Following the game session, participants will discuss their experiences and the different contexts in which serious games may be relevant.

by Cirad (Montpellier, France) and BFH (Berne, Switzerland), with the support of dP Agroforesta (Turrialba, Costa Rica).

Language: English (could be adapted to the participants' language)

*Lunch break: 12:00 to 1:30 pm*

On the stage of the Plenary Room and the coffee tables

## Logo

by Martine Crépeau, Daniel Bourgault & Luc Germain

The 5<sup>th</sup> World Congress on Agroforestry's logo was designed by Martine Crépeau, a graphic designer from Québec City.

The wooden logo was produced by technicians Daniel Bourgault & Luc Germain.

Wood species:

- Yellow Birch: *Betula alleghaniensis*,
- White Cedar: *Thuja occidentalis*,
- Sugar Maple: *Acer saccharum*,
- Black Cherry: *Prunus serotina*,
- White Pine: *Pinus strobus*.



1:30 pm, Room 200A/B

## Plenary Session: the Agroecology-Agroforestry Nexus

Agroecology is a science, a set of practices and a series of social movements emerging as a credible pathway toward more equitable, resilient, diversified, ecological and healthy food systems. Facing complex and interrelated socio-ecological challenges such as climate change, land and water resources depletion, increasing economic and social inequalities, conflicts, and food insecurity requires holistic actions. As such, agroecology proposes a comprehensive set of principles that go way beyond the spectrum of ecological agroecosystem management to encompass notions of co-creation of knowledge, social connectedness, responsible governance, and equity and agency, among others, to build food systems on viable foundations as well as to influence the political and social structures that govern them. Agroforestry and agroecology share many common grounds, and the agroforestry-agroecology nexus is mainly considered in a perspective focusing on system performances and synergies. Indeed, agroforestry can represent a highly developed form of agroecology, and applying agroecological principles in the design and management of agroforestry systems can significantly enhance their contribution to food system transition. While discussing these important connections, this plenary aims at extending the scope of the reflections by exploring how agroforestry and agroecology worlds can nurture and learn from each other on cross-cutting issues such as co-design, scaling-up, fairness, governance, advocacy, discourse framing and policy making, to ultimately foster the transition to a viable world.

### Chairs:

Fergus Sinclair, Chief Scientist at CIFOR-ICRAF & Marney Isaac, Professor at the University of Toronto and Canada Research Chair in Agroecosystems and Development

### A Yucatec Maya perspective to the interface of Agroecology and Agroforestry

Francisco Rosado-May, Founding President of the Universidad Intercultural Maya de Quintana Roo

### Scaling Agroecology through community-based intervention in Andhra Pradesh

Swati Renduchintala, Associate Scientist with World Agroforestry

### Engaging women and marginalized groups to develop agroecological landscapes in Vietnam

Mai Phuong Nguyen, Associate Scientist with World Agroforestry

### Youth leadership for agroecology and agroforestry

Genna Tesdall, Director of Young Professionals for Agricultural Development

Agroforestry for Agroecology, experiences from Tanzania

Janet Maro, Executive Director at Sustainable Agriculture Tanzania

Highlights from the Parallel Session on Agroforestry and Agroecology

Marney Isaac, Professor at the University of Toronto and Canada Research Chair in Agroecosystems and Development

*Coffee break: 3:00 to 3:15 pm*

3:15 pm, Room 200A/B

## Closing Session

A World Congress on Agroforestry is a unique opportunity to learn, share and network in order to stimulate the transition to a viable world. Through the presentation of different perspectives on the various issues discussed during the congress (farmers', philosophical, artistic as well as scientific ones), the Closing Session will permit to examine its reach while helping the congressists to project themselves into the future.

Testimonies from key participants:

- Olga Romanova, emerging professional
- Erminda Pacheco, farmer
- Samantha Bosco, academic

Congratulations to the authors of the favorite scientific posters & to Alain Cogliastro, recipient of the Gold Tree of Agroforestry Merit.

Announcement regarding the host of the 6<sup>th</sup> World Congress on Agroforestry

Christian Dupraz, President of the International Union for Agroforestry

For an imposed or chosen degrowth?

Yves-Marie Abraham, Professor at HEC Montréal

Slam, by Léo Coupal

Final thanks

5:00 pm, Room 202

## Side Event – The new FTA Partnership: what priorities ahead for agroforestry research for development?

Forests, trees and agroforestry are indispensable to achieving the sustainable development goals, including addressing the most pressing societal challenges of climate change, biodiversity loss, food insecurity and malnutrition.

A set of research and development partners have decided to work together under the FTA partnership to support stakeholders from local to international levels to achieve the transformational change that these challenges are demanding at a large speed and scale.

The purpose of this side event is to present the FTA partnership and to discuss its priorities and program of work on agroforestry.

This side event is organized by CIFOR-ICRAF and the partners of FTA.



Thursday, July 21, 2022

## Field Tours

These tours will be a great opportunity to discover, along with farmers, landowners, agroforestry advisors and researchers, innovative field work on diverse agroforestry systems and techniques such as forest farming, intercropping systems, silvopastoral systems, windbreaks and riparian buffers, but also some surprising specificities of the forestry and agriculture practices in Québec, such as maple syrup production!

Be well shod for walking in fields and bring a waterproof coat!

### Agroforestry for biodiversity – touring three sites on Côte-de-Beaupré

This day will be an opportunity to visit three very different agricultural enterprises, but all of which are committed to improving biodiversity through agroforestry.

The first visit will take place at the Bioferme des Caps farm. Dominique Bouchard uses permaculture principles to grow organic berries and plants to produce kombucha. Since 2016, several windbreaks and biodiversity islands have been established to increase plant and wildlife diversity. These landscapes contain a wide variety of species, many of which are used to produce kombucha. The visit will end with a tasting of this beverage with so many virtues!

The second visit will take place at Les Canardises, where the Klein family raises ducks in outdoor pens. Numerous windbreaks of several rows have been planted to increase biodiversity and to improve the connectivity between the existing wooded lots. The originality of this operation lies in the establishment of about 60 islands of trees and shrubs, inside the pens, which also provide protection to the ducks against bad weather. A tasting of their unique products is planned.

After a meal at the Auberge Baker, one of the best restaurants on the Côte-de-Beaupré, the last visit will take place at the Ferme des Sept Crans, owned by the Fortin Robitaille family. To get there, a 20-minute walk is required. It is a beautiful example of intercropping, consisting of cereal beds placed between hedges made up of nearly 40 different species and spaced at 30-40 meters. The visit will end on a shaded mushroom production site (shiitake, oyster mushroom, hedgehog).

Organized by the Forestry Education and Research Center, CERFO, Emmanuelle Boulfroy

The visit tour: <https://goo.gl/maps/anbTYBPMov3HmWoC8>

144 km trip

7:30 am to 5:30 pm

Lunch at a local restaurant

## The cultivation of medicinal plants under planted tree cover and sugar maple products

Medicinal plants, already used by First Nations, have been the object of renewed interest for several years now. Unfortunately, the growing demand for medicinal plants is leading to an increase in harvesting and threatening wild populations. Cultivation under forest cover makes it possible to protect the latter while offering the owners of forest stands or plantations the possibility of enhancing them.

This is the choice made by Jean Arsenault, in 2003, when he planted various species of medicinal plants in his plantation of oaks and sugar maples in Saint-Jean-Chrysostome, on the south shore of Quebec. The site you will discover is an agroforestry system that is unique in Quebec, combining noble hardwoods with medicinal plants such as goldenseal (*Hydrastis canadensis*), Canada wild ginger (*Asarum canadense*), Canadian bloodroot (*Sanguinaria canadensis*) and American ginseng (*Panax quinquefolius*). The owner manages his plantations to produce quality wood while maintaining the shade required by each cultivated undergrowth crop. The intercrops are intended for the processing market by herbalists or for the development of new crops. Some of these products will be presented to you on the site. You will be able to taste Canadian wild ginger Gin or discover medicinal products made from goldenseal grown on the site.

To extend the discovery of products from Quebec forests, we invite you to spend the afternoon on the theme of sugar maple, the emblem tree of Canada. Maple syrup is part of the cultural and gastronomic identity of Quebec, which provides 70% of global harvest. The sugar farm Érablière du Cap, in Lévis, opens its doors to introduce you to the profession of maple syrup producer. After a traditional meal in the sugar shack, the Center for Research, Development and Technology Transfer of Maple Syrup (Centre ACER) will offer a conference on the details of this sector and the results of its research, as well as a tasting of different syrups.

This day of visit will give you an overview of the emerging sector of medicinal plants and the famous maple syrup sector through the eyes of passionate professionals.

Organized by Jean Arsenault and Marie Dromain

1563, chemin Beauséjour, Lévis.

Visit of two sites = 2 stops

The visit tour: <https://goo.gl/maps/1QcuLyVcfo8HmaVVA>

85 km trip

8:30 am to 5:30 pm

Lunch in a sugar bush - Érablière du Cap 1925 Ch Lambert, Lévis, Quebec, Canada 418-831-8647



## Agroforestry tour in the Lower St. Lawrence: valorizing bioproducts from agroforestry

The Bas St-Laurent is the cradle of agroforestry in Quebec. Over the past forty years, some one hundred kilometers of hedges have been built to protect crops, waterways, buildings and livestock, as well as road infrastructures. Under the impetus of Biopterre and the Institut de Technologie Agricole de La Pocatière, many projects aiming at valorizing the bioproducts resulting from agroforestry developments have also been implemented.

This tour provides a unique opportunity to visit 6 sites where these projects are being carried out and to see the range of possibilities offered by agroforestry: hazelnut production, non-timber forest products under a maple canopy, small fruit and biomass production in hedgerows, agroforestry intercropping. Lunch will be served along the river in the beautiful village of Kamouraska. At the end of the day, you will be treated to a gin tasting that incorporates juniper (*Juniperus sp.*) from the test plots of the Centre d'expertise en bioressources (Center of expertise in bioresources) Biopterre.

Organized by Biopterre's André Vézina and Maxime Tardif

Visit of 5 sites + 1 restaurant = 6 stops

The visit tour: <https://goo.gl/maps/biTvnxyQeHoTibqc9>

468 km trip

7:30 am to 6:30 pm

Gin tasting, Lunch at a local restaurant, Snack box



## Visiting on-farm silvoarable agroforestry trials and a sugarbush in the Centre-du-Québec region

A first stop will be made at the Bertco farm where two schemes experimenting with intercropping agroforestry systems (50 to 65 trees/ha) will be presented. The systems were established in 2012 and 2021 and cover nearly 15 ha. Hybrid poplars and different hardwood tree species are associated with different crops in rotation (corn, soybean, barley, forage crops). In the older system, various research studies have evaluated tree establishment success, crop yields, soil microbial community structure and diversity, soil carbon stocks and microclimatic conditions. Some results from this research will be presented.

A second stop will be made on a farm located in the floodplain of Lake St. Pierre. Lake Saint-Pierre covers nearly 350 km<sup>2</sup> and is recognized by UNESCO as a biosphere reserve. Several ongoing projects aim to develop crops and agricultural practices adapted to the specific context of the vast cultivated shorelines of Lake Saint-Pierre and which have a positive impact on the quality of this exceptional agroecosystem. Some of these projects will be presented.

A third stop will be made on a farm specialized in maple syrup production. After a traditional meal in the sugar shack, a conference on the production and transformation of maple syrup will be presented. Participants will be invited to taste different syrups. The maple grove and the maple water harvesting and processing facilities of the farm will be open to visitors.

Organized by David Rivest from l'Université du Québec en Outaouais

Visit of 2 sites and a maple grove

The visit tour: <https://goo.gl/maps/h3SUnU1iuwLk5cgZ7>

343 km trip, 3h56 drive

7:30 am to 6:30 pm

Lunch in a maple grove, Snack box

<http://www.erabliereprince.ca/>



10:30 am, Université Laval, Kruger Building, room 2230

## Agroforestry and Climate-Resilient Land Use: A Global Perspective

*Conference by P.K.R. Nair, University of Florida*

Climate-Resilient Land Use refers to the sustainable use of existing natural resources for crop and livestock production systems to mitigate the impacts of climate change and achieve higher productivity in the long term.

Sequestering carbon in biomass and soils: Photosynthetic C captured by trees and its long-term storage in plant biomass is an effective strategy for limiting the rise of atmospheric CO<sub>2</sub> concentrations across the globe. Compared with treeless land-use systems, Agroforestry systems (AFS) have higher C seq. potential because of their higher plant diversity, larger biomass volume per unit area of land, and ability to store C in the biomass and soils for longer periods.

Ecosystem Services of Agroforestry and Climate-change Mitigation: Over the years, Ecosystem Services (ES) as applied to agroforestry have come to embrace a wide variety of services. Two prominent ones are climate-change mitigation and biodiversity conservation. Agroforestry systems also play significant roles in realizing such services based on hydrological processes. The extent to which these benefits can be realized depends on several site-specific and management conditions. The manifestation of the advantages is a slow process, and its impact will be felt only gradually, which could be a disincentive to those expecting a rapid turnaround.



## Description of Parallel Sessions

### Transitioning to a Viable World

Agroforestry offers many benefits for transitioning to a viable world. In these sessions, researchers will dialogue with farmers and various stakeholders to explore the different ways by which agroforestry can bring solutions to different ecological, social and economic needs and challenges. Each session aims to present lessons that can be learned from farmers' innovations, research projects, development initiatives and policies in order to help farmers, advisors, researchers and policy makers to contribute to agroforestry development for a transition to a viable world.

#### A. Transitioning to Healthy Soils

A healthy soil can function as a living ecosystem that sustains biological productivity while maintaining the quality of the abiotic environment and protecting all life forms on a global scale. It is an important indicator of agricultural sustainability. Agroforestry systems are regenerative and sustainable land-use practices that contribute to improving soil health. They enhance soil organic carbon storage, nutrient availability, soil structure and microbial community diversity. These are key factors that contribute to increasing the diversity of life forms in the soil and improve its health. However, to what extent can agroforestry systems fulfil this role? What conditions are needed for agroforestry systems to maximize soil health and productivity? Questions like those are still unresolved and require more research. The aim of this session is to discover pathways for agroforestry to contribute to transitioning to healthy soils.

#### B. Transitioning to Better Water Balance and Light Valorization

Water is a key resource in agricultural systems and finding ways to improve its management is critical for more sustainable practices. The integration of trees in those systems can improve the soil water balance and thus promote water use efficiency through higher infiltration, retention of water into soils and lower water losses due to evaporation and runoff. Agroforestry also plays a key role in water quality since trees promote sediment deposition and nutrient retention, contributing to reduce their movement into ground water and helping to clean runoff water. By making a better use of the available light, agroforestry systems also contribute to a better valorization of this resource for plant production. However, to what extent can agroforestry fulfill this role? How does the presence of trees in a landscape modify the local climatic conditions? What conditions are needed for agroforestry systems to maximize water balance and light valorization? This session aims to find ways for agroforestry to contribute to transitioning to a better water balance and light valorization.

## C. Transitioning to Biodiversity

The conversion of vast natural areas to crop fields and pastures threatens the habitats of many species, compromising ecological sustainability. Ecosystem complexities need to be considered and promoted through agricultural systems that contribute to conserving natural resources by providing food, water, shelter and habitat for wildlife. Agroforestry systems, which typically harbor a much higher species richness than monoculture systems, are essential to protect and increase biodiversity in agricultural landscapes. They can also function as ecological corridors, allowing species to move between different habitats in a fragmented landscape. Agroforestry systems offer high complexity that can promote natural enemies of crop pests, while also providing a better habitat for pollinators and other beneficial taxa, such as soil microbes. Biodiversity is also the base to provide provisioning services (diversified production), regulating services (carbon sequestration, pest regulation, hydrological regulation, conservation of soil fertility) and even cultural services (tourism, recreation, spiritual). But how does agroforestry play such roles? To what extent can agroforestry compensate for the loss of natural habitats? What can be done to improve contributions and avoid conflicting aims? This session aims to find ways for agroforestry to contribute to transitioning to higher, and productive, biodiversity on farms and at the landscape level.

## D. Transitioning to a Viable Climate

Agroforestry systems help mitigating climate change in the long run through carbon sequestration in soil and trees and lower levels of methane and nitrous oxide emissions compared to agriculture without trees. They thus contribute to meeting global climate change mitigation targets. By providing better resistance and resilience to biotic and abiotic stresses, agroforestry could also help to adapt to climate change. Thanks to the shade they provide, trees offer protection for crops, livestock and farmers against extreme climate phenomena such as rising temperature. By reducing soil evaporation and crop transpiration and increasing water infiltration, they could help to resist to episodes of low and erratic rainfall. Agroforestry also increases farmers' resilience through crop diversification by providing resources such as fruits, nuts, medicinal products and timber, therefore ensuring a secure source of income. It is one of the cheapest adaptation strategies for low-income communities, which are more at risk when facing climate change due to increased exposure and vulnerability. But to what extent does agroforestry help mitigating climate change and adapting to it? What conditions are needed for ensuring that agroforestry can play its role? How does it compare with other "climate-smart" options, in terms of efficiency and affordability? Can we upscale at global scale the potential impact on the climate of a generalization of agroforestry? This session aims to find ways for agroforestry to contribute to transitioning to a viable climate.



## E. Transitioning to Food Security and Health

Agroforestry's multifunctional landscape resulting from diversification can provide a healthy and balanced diet to households. Agroforestry systems can benefit food insecure families and communities, and especially women and children, to derive nutritious food from crops, livestock and trees, as well as non-timber tree products that can be a source of income. Further, by reducing the dependency on chemical inputs, they can lower the risk caused by those inputs on human health. By improving ecosystem diversity and processes, agroforestry may also help combating zoonoses and other human diseases. Overall, agroforestry can play a critical role in improving food availability, access (via increased household income), utilization (via value-addition), and stability, which all contribute to achieve sustainable food security and better health. However, why is food insecurity still an issue? Are we lacking in any supporting infrastructure, governance and policies? How do we conceive agroforestry systems that really ensure food security and health? This session aims to find ways for agroforestry to contribute to transitioning to food security and human health.

## F. Transitioning to a Viable Economy

Agroforestry improves soil health, biodiversity and resilience to climate change, thus enhancing crop yield and income generation. It promotes an economic diversification which is especially adapted for smallholder farmers that are vulnerable to biotic, abiotic and economic stresses. Through diversification of the agroecosystem, agroforestry provides different types of resources for additional income or to reduce households' expenses, thus participating in reducing farmers' dependency on inputs and credit. However, agroforestry may also limit yields of certain species in comparison with monospecific systems, due to the competition between the associated species for resources. Agroforestry is also commonly associated with agroecological practices that might not be valorized by any label on the market. It provides many ecosystem services whose economic value for the society as a whole is considerable but often not paid for. Putting agroforestry in practice to generate profit thus rises many technical, commercial, organisational, and economic challenges. What are the conditions for agroforestry systems to be profitable at the farm scale? How can agroforestry systems be included in a landscape to favor a transition to a viable and environment-friendly economy, and eventually to a circular economy? This session aims to find ways for agroforestry to help transitioning to a viable economy.

## G. Transitioning to a Viable Society

Recognizing agroforestry as a land use that increases basic resources availability and reduces farmers' vulnerability, in particular for women smallholders, can help rural households and regional economies to increase self-reliance. Many agroforestry systems are embedded in people's culture, especially in First Nations and other indigenous people, bringing sense to their cropping practices in a world where forestry and agriculture have not been segregated. As a multifunctional approach, agroforestry also contributes to a more appealing landscape and improved spatial planning in rural communities, as well

as in some urban and peri-urban contexts. However, to what extent can agroforestry fulfil this role? What conditions are needed for agroforestry systems to maximize communities and societies' sustainability? This session aims to find ways for agroforestry to help transitioning to a viable society, while maintaining viable rural societies wherever they exist.

## H. Transitioning to a Viable Development

As a multifunctional approach, agroforestry connects the need for profitable livelihoods, quality of human lives and healthy ecosystems. It contributes to many sustainable development goals as diverse as poverty reduction, biodiversity conservation, sustainable land management, gender equality, health, access to clean water and sustainable energy solutions. By its production of multiple resources on a given unit of land and its promotion of ecosystem diversity, agroforestry represents a promising path for the critical transition to healthy agroecosystems and sustainable development. However, the implementation of agroforestry practices faces many challenges related to the use of local knowledge, farmers' participation, availability of appropriate technologies, research, education and training, among others. This session aims to find ways for agroforestry to help transitioning to a viable development.

## I. Transitioning to Viable Policies

To increase resources dedicated to the implementation of agroforestry in the field, policymakers' attention must shift from conventional industrial models to more sustainable approaches. Because of the multifunctional nature of agroforestry systems, a multisectoral coordination is required to facilitate producers' transition to agroforestry and limit factors that restrain farmers' long-term investments such as lack of rights to land, lack of technical and financial support and inadequate agricultural and forestry policies. This session aims to find ways for transitioning to a viable policy environment that could support agroforestry conservation, adoption and scaling-up.

## Agroforestry Solutions for Transition

Agroforestry was first developed locally by rural and indigenous communities all around the world. It thus comprises very diversified systems and techniques based on broad traditional knowledge. Farmers are also constantly innovating, sometimes in dialogue with other actors such as researchers and agroforestry advisors, emphasizing the need for contextual and systemic approaches when studying or implementing agroforestry systems. In these sessions, farmers, advisors, researchers and policy makers will explore together local agroforestry solutions based on farmers' knowledge and continuous innovation to improve existing systems and develop innovative agroforestry solutions for transition.



## J. Which Agroforestry for Arid Climates?

The land use in arid and semi-arid climates of the world including dry woodlands and savannas has the challenge of providing food for important populations of humans and livestock. But ecophysiological factors including growth resources like water limit the agroecosystem productivity, while social factors such as increasing human population, high demand for wood biofuel, insecure land tenure and unaffordable farm inputs put even more pressure on farmers' ability to get sufficient food and income for supporting their needs. While it is necessary to meet the global development agenda of the Sustainable Development Goals (SDGs), especially food security and eradication of poverty, the use of un-adapted agriculture practices have resulted in loss of tree cover, overgrazing, reduced soil health and desertification. At the same time, from oasis and homegardens to agroforestry parklands, using bocages, windbreaks or live fences, farmer communities have developed various agroforestry systems and techniques for adapting to such a difficult environment. In this session, we will explore what can be learned from local traditional systems, farmers' innovations and scientific research to conceive agroforestry systems able to boost productivity and improve food security and nutrition while reducing disaster risk and providing ecosystem services in these arid climatic regions of the world.

## K. Which Agroforestry for Annual Crops?

Annual crops mixed with trees give room to interactions which have always been a key element determining the management options applied by farmers. Both in tropical and temperate zones, choosing the compatible species, their spatial and temporal arrangement and the management practices to apply are critical to optimize the overall production of any specific agroforestry system or technique and the ecosystem services that they provide. Biophysical studies include a combination of field trials, observational studies and modelling to understand soil-tree-crop interactions, mainly regarding the sharing of growth resources such as soil nutrient, water and light, as well as structural and functional biodiversity. On the other hand, qualitative and quantitative studies point out various social, economic and policy factors affecting farmers in their practice. Despite farmers' innovations and scientific advances, there are still some methodological challenges in determining the trade-offs and synergies between and among goods and services, and how to boost the provisioning, supporting, and regulating functions of such agroforestry systems. In this session, we will explore what can be learned from local traditional systems, farmers' innovations and scientific research to conceive agroforestry systems for annual crops that will provide such critical ecosystem service functions in the quest for ensuring food security while achieving adaptation and mitigation goals in face of changing climate.

## L. Which Agroforestry for Commercial Perennial Crops and Trees?

Monoculture in full sun conditions was usually recommended in tropical perennials such as coffee, cacao, oil palm and temperate perennials such as fruit trees. Nowadays, associating trees, planted on hedgerows or inside plots, are advocated due to the wide range of ecosystem services that they

provide. New concepts and tools are available to help in selecting locally adapted tree species and in analyzing trade-offs between the provision of ecosystem services and societal and farmers' needs, constraints and preferences. Building on local traditional systems, farmers' innovations and most recent scientific research, this session aims to explore advances in tropical and temperate agroforestry systems with perennial crops, covering experiences on the complementarity or competition for resources as well as biodiversity conservation, diversification of revenues, avoided deforestation, climate change mitigation and adaptation, soil and landscape restoration, agricultural regeneration, regulation of the water cycle, biocontrol of pests and diseases, and entry point for landscape governance and community resilience.

### M. Which Agroforestry for Integrating Livestock to Trees and Crops?

The association of animals, crops and trees is one of the most common features of traditional agroecosystems in the world. While industrial models of agricultural production bet on a spatial separation of crops and livestock, not mentioning trees, a great diversity of agrosylvopastoral systems exists. In such systems, trees and shrubs may be used for various purposes such as feeding animals through foliage or fruit production and offering them shade and protection against winds, but also for providing timber, fuelwood, food for human consumption, medicinal products, litter, wildlife habitat, carbon sequestration and various sociocultural benefits. Locally, many rural communities developed innovative techniques for ensuring such a multifunctional use of their landscape, benefiting from the complementarity between the components of agrosylvopastoral systems. At the same time, there are increased concerns about the impacts of livestock on the ecosystems and its contribution to climate change. What kind of trees, shrubs, crop varieties and animal breeds may be used in agrosylvopastoral systems? How can we manage them? What kind of landscape may fulfill such integration? Which regulation can meet the needs of agrosylvopastoral farmers and communities? In this session, we will explore what can be learned from local traditional systems, farmers' innovations and scientific research to conceive agrosylvopastoral systems able to contribute to food security, income and sociocultural needs of farmers' communities, while ensuring the achievement of a viable future.

### N. Which Agroforestry for an Edible Food Forest?

From agroforests to edible forest gardens and permaculture, domestic forests exist all over the world, from temperate to arid and tropical humid regions, where they have been managed by indigenous and farmer communities for centuries. These domestic forests have been designed and periodically re-designed building on the existing ecosystem in relation to socioeconomic and cultural needs and values, through practices adapted to the local context. They provide various timber and non-timber products such as fruits, nuts, mushrooms, medicinal products, resins, fibers, rubber, etc., thus contributing to food security and income. Domestic forests are also complex natural ecosystems that offer many environmental benefits such as forest preservation, biodiversity protection, climate change mitigation, soil conservation and retention of water into soils, as well as various sociocultural benefits. Those

elements are essential for global environmental and human health and can therefore participate in the pursuit of sustainability. However, domestic forests are affected by many challenges related to the use of local and ancestral knowledge, negative perceptions about forest farmers, and unsuitable forest policies and regulations. In this session, we will explore the conditions needed for a nourishing forest to be a promising alternative strategy for the management of forest resources, lands and landscapes, while promoting local knowledge and livelihood activities.

### O. Agroforestry – an Essential Pillar of Agroecology

Contemporary interest in agroecology has emerged in response to evidence of widespread problems associated with the corporate-led, industrial model of agricultural production. Agroecology has evolved as a field that focuses on the application of ecological principles to agricultural research and practice, to an approach that engages producers, harvesters and the entire food system and seeks broad participation of a diversity of knowledge systems. This approach aims to transition away from ideologies that have prioritized maximizing agricultural yields with synthetic inputs to one that encompasses various aspects of socio-ecological systems thinking, and which aims to support local economies while strengthening biodiversity, resilience, and social justice. This session will explore how agroecological principles can inform agroforestry transformations, as well as the role of agroforestry in promoting and/or inhibiting agroecological transitions. We will explore the deeper changes needed in the ways our agroforestry systems are conceived and structured to transition toward more equitable and sustainable futures.

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<b>A. Transitioning to Healthy Soils</b>	
<p><b>Impact of ramial chipped wood amendments on soil physicochemical properties and fungal community at two sites in Benin</b></p> <p>The application of ramial chipped wood (RCW) to soils is a useful agroforestry practice for soil restoration, and enhancement of organic carbon storage within soil ecosystems. RCW refers to the leafless branches (diameter &lt; 7 cm) from trees and shrubs, preferentially from hardwoods, which are shredded and applied to soils by mulching or by direct incorporation. The goal of this study is to investigate the effect of soil amendments with RCW of <i>G. arborea</i> and <i>S. latifolius</i> on soil properties and humic acid in a split plot experimental design in northern and southern Benin. The treatments were as follows: volume of water irrigation (V1 and V2=1/2V1) and organic amendment '(45 t/ha of RCW, 15 t/ha of poultry manure (PM), RCW_PM (45 t/ha of RCW and 15 t/ha of PM) and control)'. Topsoils were sampled before and after 24 months of in situ organic amendment application. RCW treatments (RCW and RCW_PM) contributed significantly to organic carbon storage and soil nutrients (N, P, K, Ca, Mg) increase (the latter by up to 1.5 times) compared to the control. Humic acid (HA) was extracted from soil and purified prior to infrared spectroscopy, nuclear magnetic resonance, and Py-GC-MS analyses. The results showed that the soils amended with the RCW produced a significant amount of HA. A high concentration lignin-related compounds was observed in pyrolysis products from HA from RCW amended soils. Using the Illumina Miseq sequencing of the ITS2 region, RCW amendments significantly changed fungal compositions with increased relative abundance of Ascomycota (up to 92% of total fungal community), Mucoromycota, Basidiomycota and Rozellomycota. These fungal phyla contain species that participate in organic matter decomposition and compound transformations. Our results suggest that the amendment of RCW after 24 months in Benin sandy loam soils, significantly increased fungal activity and improved soil nutrient availability. Hence, this technology could be recommended for regenerative agroforestry.</p>	<p>Daassi, Rodrigue Khasa, Damase Stevanovic, Tatjana</p>
<p><b>Effects of partial rainfall exclusion on root growth and mycorrhizal colonization of soybean in a tree-based intercropping system in southern Quebec</b></p> <p>Tree-based intercropping (TBI) systems may have important effects on the belowground interactions among trees, crops and mycorrhizal associations. These effects have not been assessed in a well-documented manner in a context of decreasing rainfall. The objective of this research was to study the impacts of a TBI system, a tree root pruning treatment and a partial rainfall exclusion treatment on the dynamics of soil colonization by soybean roots and the rate of soybean root colonization by arbuscular mycorrhizal fungi (AMF) using the intersection method. This research was conducted in a TBI system established in 2012. High-value hardwood species and hybrid poplars were planted alternately every 5 m along each tree row and 40 m apart, resulting in a stand density of 50 stems ha<sup>-1</sup>. The rain exclusion experiment was installed in the summer 2019 (July to September) at 4, 12 and 20 m from the tree rows in the TBI system and in an agricultural control without trees (replicated in seven blocks). Length of soybean roots classified by diameter intervals (<math>\leq 0.5</math> mm; 0.5-1.0 mm; and <math>\geq 1</math> mm) and total root volume and weight (fresh and dry) were higher in the first 0-10 cm. Soil depth had an interaction with rain exclusion on soybean root growth. Soybean roots <math>\geq 1</math> mm were more abundant in the 20-30 cm depth in plots where rain was excluded. We</p>	<p>Gagné, Geneviève Lorenzetti, François Chagnon, Pierre-Luc Rivest, David</p>

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also observed an increase of root length (for the three diameter intervals) in plots where tree roots were pruned. No difference in root mycorrhizal colonization rates for all distances from tree rows and treatments were found. This study will help to better understand belowground ecological interactions in TBI systems.	
<b>Soil biodiversity and soil physical properties in a banana-based agroforestry system</b> Faced with the reduction of natural resources and climate changes, the development of agroecological practices reducing the dependence to chemical input is becoming urgent. Banana-based agroforestry system could be interesting for improving soil carbon storage, reducing erosion and promoting soil biodiversity. In Martinique, innovative banana farmers already started to grow banana for exportation in agroforestry systems. The aim of this study is to evaluate the effect of tree introduction on soil inveterate communities and the soil ecosystem services associated in real condition of production. To this purpose, three banana-based agroforestry fields were compared to three conventional banana fields (without tree). All fields had the same date of plantation, the same agronomic practices and the same soil type to avoid confounding factors. Abundance, biomass and biodiversity of soil macrofauna were measured annually during three years. The last year, soil infiltration rate, soil carbon storage, soil micro- and macro-porosity were measured. Biodiversity results from the first year show a contrasted response of each invertebrate taxa: Isopods, spiders and earwigs abundance were more impacted than other groups and showed a marked increase in agroforestry system. Earthworms abundance was not impacted but there was an increase the epigeic functional group observed only in agroforestry system probably due to an increase of standing litter mass. These trends were mirrored by a slight increase in porosity in the agroforestry systems, that was mostly attributed to changes in micro and mesoporosity. This led to slightly higher water retention capacity and lower soil bulk density in agroforestry systems. Contrastingly, macroporosity and infiltration rates did not change with the system.	Mathieu, Coulis Marie, Sauvadet Christiane, Mauriol Laurent, Gervais Loïc, Normand Joanie, Edmond-Castaing Loïc, Monsoreau Nelly, Belliard Eliane, Marville
<b>Spatial and temporal dynamics of microbial parameters in northeastern French agroforestry systems</b> Agroforestry is defined as the association, at the field scale, of trees and agricultural stand, culture or grassland which can be grazed or not. Agroforestry appears as an ecological diversification for the farmers in the French context even if technical-economic references and the evaluation of ecosystemic services inherent to tree introduction are currently lacking in the north-east part of the country. In this context, the goal of our experiment was to evaluate the impact of tree introduction on one soil regulation service corresponding to the ability to furnish inorganic nitrogen for plants through microbial soil organic matter mineralisation. Six alley cropping agroforestry systems differing in terms of pedoclimatic conditions, cropping systems (silvoarable versus silvopastoral systems) and tree diversity scattered throughout the northeastern part of France were monitored since 2019. Soil samples (0-15 cm depth) were collected at varying distances from the trees and different microbial parameters relative to abundance and activity of microbial communities were measured and analysed in relation to soil organic carbon and nitrogen pools and other physico-chemical parameters to predict tree effect on potential nitrogen net mineralisation fluxes. Our main hypotheses were that microbial abundance and activity (i) are greater close to the trees because of the litter deposition of trees, (ii) are less affected by the presence of the trees in silvopastoral systems than in silvoarable systems due to an organic matter content higher and less soil perturbed in grassland soils	Piutti, Séverine Laflotte, Alexandre Dallé, Erwin Genestier, Julie Marron, Nicolas

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compared to annual crops. The first results showed that microbial parameters are more strongly dependant on the kind of agroforestry systems and pedoclimatic conditions than on the proximity of the trees. In general, if the labile carbon content decreased from the trees to the middle of the field, microbial abundance and activity showed a site-specific response pattern.	
<b>Impact of poplar-clover agroforestry system on root traits and microbial communities in controlled conditions</b> The central hypothesis of agroforestry systems is based on an optimized use of resources of the environment by the associated species due to a differentiation or spatial segregation of niches allowing the coexistence of the latter without competitive exclusion. Today, the mechanisms of interaction between species that determine whether agroforestry associations will be more productive than the corresponding monospecific stands are still poorly understood, especially at the below-ground level. The root characteristics and the associated microbial traits are still little discussed due to the complexity of their understanding in situ. The objective was to follow over a 3-month period the temporal evolution of above-ground biomass acquisition together with the root traits using WinRhizo, soil organic carbon and inorganic nitrogen pools and microbial abundance and activity (microbial biomass and enzymatic activities related to biogeochemical cycles) of the poplar-clover association grown in pots under controlled conditions in comparison with each species in pure treatment. From the second month, a competition effect of the mixture is visible both on the aerial parts of the poplar and on the root traits of the two species, with a smaller root surface per species in the mixture than in pure cultures, while the total root surface per pot is not different. No differentiation of root traits towards more acquisitive traits (in this case finer roots) in the presence of the agroforestry association was observed. At the soil level, no difference was found for both species between the treatments in terms of microbial biomass, soil hot water soluble carbon or inorganic nitrogen content. The enzymatic activities of phosphatase, beta-xylosidase, N-acetylglucose-aminidase increased significantly overtime, reflecting an increase in root activity, without any difference between treatments. Beta-glucosidase, arylsulfatase and leucine amino peptidase decreased over time, with no difference between treatments.	Piutti, Séverine Le Mouél Cédric, Cédric Marron, Nicolas Dalle, Erwin Priault, Pierrick
<b>Effect of alley cropping and nitrogen levels on cauliflower and stem amaranth productivity and soil fertility</b> Gradual decline of soil fertility in Bangladesh is alarming for sustainable crop production. Agroforestry especially alley cropping system is an important alternative crop production system that may help maintaining soil fertility. Two experiments were done to study the impact of alley width and nitrogen doses on productivity of cauliflower and stem amaranth in alley cropping system during 2017-2018 and 2018-2019 growing seasons at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh in a split-plot design with three replications. Three alley widths viz. 3.0 m, 4.5 m and 6.0m along with control comprised factor A and four nitrogen doses namely full recommended dose, 75%, 50% and 25% of the recommended doses with control comprised factor B. The results revealed that both cauliflower and stem amaranth yielded the highest in 6.0 m alley with 100% recommended N fertilizer. Cauliflower yield was 33.55 t/ha and it was 55.57 t/ha for stem amaranth. The yields were statistically at par when 50% of the N fertilizer was reduced with the higher Benefit coast ratio compared to control. The BCR was 3.23 for cauliflower when grown in 6.0 m alley along with 50% less N fertilizer when the control plot had less than 2.00. It was 5.33 for stem	Saha, Satya Ranjan Miah, Md. Giashuddin Rahman, Md Abiar Islam, Md. Rafiqul Alam, Jobaydul



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amaranth with same alley width and N dose. Soil chemical parameters like organic carbon (0.94%), total N (0.21%), available P (16.26 ppm), exchangeable Ca (2.54 meq/100g) and exchangeable Mg (0.899 meq/100g) were found the highest in alley cropping system compared to control plots in case of cauliflower. Similar trend was also observed in stem amaranth. Cauliflower and stem amaranth cultivation in alley (6.0 m) with 50% less N fertilizer is profitable and also help improve soil fertility.	
<b>Response of tree lopping and organic manures on soil bacterial population in <i>Phaseolus vulgaris</i> under Morus based Agroforestry System</b> The study's goal was to investigate soil bacterial count in <i>Phaseolus vulgaris</i> + <i>Morus alba</i> based agroforestry system with four tree lopping intensity (0%, 25%, 50%, and 75%) and five manure doses treatment (S1-FYM, S2-Jeevamruth 5%, S3-Jeevamruth 10%, S4-RDF+FYM, and S0-No Manures) in split plot design. The average maximum available bacterial count (18.96 cfu gm <sup>-1</sup> ) was found in T0 (no lopping), whereas, it was minimum (17.23 cfu gm <sup>-1</sup> ) in T3 (75 per cent tree lopping intensity). In case of different manure treatments, the average maximum bacterial count (21.73 cfu gm <sup>-1</sup> of soil) was observed in S1 (FYM), whereas the minimum (14.62 cfu gm <sup>-1</sup> of soil) bacterial count was recorded in S0 (no manure) treatment. Therefore, it was concluded that both tree lopping intensities and organic manure applications affected the soil significantly. It was further observed that soils under trees with no lopping and FYM gives good results in the bacterial count, which ultimately increases the soil fertility and leads to higher production along with soil conservation.	Chauhan, Saakshi Thakur, Chaman Lal Bhardwaj, Daulat Ram Bhatia, Avinash Kumar
<b>Soil organic carbon sequestration potentials in hybrid poplar afforestation plantation in Southern Ontario, Canada</b> Carbon sequestration via afforestation land-use is a natural climate solution (NCS) that could contribute Canada's climate change mitigation targets. A study was conducted in four sites in southern Ontario, Canada (located in Guelph, Claremont, and Kemptville) to understand the potentials of poplar ( <i>Populus</i> Spp.) afforestation systems (1100 trees ha <sup>-1</sup> ) in enhancing soil organic carbon (SOC) influenced by agroclimatic conditions and clonal types. SOC gains were quantified on an equivalent soil mass basis at 0-30 cm soil depth for 11 different poplar clones by comparing SOC derived in 2020 with the existing baseline data. Clones' adaptability to three levels of land suitability in southern Ontario was also assessed. Result from this study showed that SOC sequestration gain in hybrid poplar plantations ranged from 10.4 to 23.94 Mg C ha <sup>-1</sup> . Clone DN-154, with a mean annual SOC gain of 1.89 Mg C ha <sup>-1</sup> y <sup>-1</sup> showed the highest SOC sequestration gain among all studied poplar clones. However, DTACs clones did not contribute much to SOC sequestration. In relation to site suitability indices, there was no significant difference (p>0.05) in annual SOC sequestration rates. However, the best site suitability index showed numerically the highest annual SOC sequestration rate of 1.61 Mg C ha <sup>-1</sup> y <sup>-1</sup> . This study demonstrated that selected clones of hybrid poplar in all four research sites positively influenced SOC gains. This study also found that the oldest site (Guelph, established in 2005), had the highest SOC sequestration during the 15-year period, however, as the trees are degrading in this site, future soil carbon gain is doubtful. Therefore, proper management strategies should be put in-place to hold the gained SOC in sites that are more than 15 years old.	Bazrgar, Amir Sidders, Derek Alphons, Andrew Thevathasan, Naresh



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<p><b>Litter decomposition of three plant species with silvopastoral potential in south-eastern Mexico</b></p> <p>Litter decomposition is one of the main nutrient recycling processes to the soil in silvopastoral systems and is more efficient than in pastures monocultures due to the diversity of trees or shrubs species and their chemical composition. The aim of this study was to evaluate the decomposition and nutrient release patterns of <i>Tithonia diversifolia</i>, <i>Moringa oleifera</i> and <i>Leucaena leucocephala</i>, in southeastern Mexico. Senescent leaves of the three species were placed in the decomposition bags, which were placed on the ground in a forage bank. The remaining samples were collected in five periods (15, 30, 60, 120 and 240 days of decomposition). The remaining material in each period was determined the contents of dry matter (DM) and organic matter (OM), Lignin, nitrogen (N) and carbon (C) and the C: N and Lignin:N ratio was estimated. The initial chemical characteristics of senescent leaves differ between species. The initial decomposition constants of DM and C were similar, while the constants of OM, Lignin and N, differ between species. Likewise, the relative decomposition rates (k) of DM, MO, Lignin, C and N are different between species. From 30 to 240 days of decomposition, <i>L. leucocephala</i> maintained the highest DM, OM and C remaining compared to <i>T. diversifolia</i> and <i>M. oleifera</i>. On the other hand, from 60 to 240 days, <i>L. leucocephala</i> maintained the greater content of N and Lignin remaining, compared to the other species. The species <i>M. oleifera</i> and <i>T. diversifolia</i> showed a high potential to reintegrate OM in the short term, since 98.2% and 99.9% of the soil litter decomposes in a period of 240 days. These species represent an alternative for the reintegration of N and OM in the short term in production areas that have been exploited by overgrazing and/or intensive agriculture.</p>	<p>Cabañas-Gallardo, Alberto Aryal, Deb Raj Estrada-Medina, Héctor Casanova-Lugo, Fernando Lara-Pérez, Luis Ramírez-Barajas, Pablo Jesús Villanueva-López, Gilberto Oros-Ortega, Iván</p>
<p><b>Dispersed trees on pasturelands increase carbon stocks in livestock systems in the humid tropics of Mexico</b></p> <p>The permanence of trees in agricultural lands is an option to increase carbon (C) reserves. However, the contribution of dispersed trees in pastures has been little studied in the cattle grazing systems of the humid tropics of Mexico, despite being one of the most used silvopastoral modalities. Here, we studied C storage in biomass and the soil in a livestock system made up of <i>Brachiaria brizantha</i> grass associated with dispersed trees in pastures (DTP), compared to a livestock system made up of sole <i>Brachiaria decumbens</i> grass without trees (GWT). We randomly selected five sample plots, with a size of 1000 m<sup>2</sup>, for each livestock system. At each site, tree biomass was estimated using allometric equations, while grass and ground litter and soil organic carbon at different depths were quantified by direct sampling methods. Of the total biomass in the livestock system with DTP, above-ground biomass contributed 57.3%, below-ground biomass 20%, and litter 22.7%. In the case of the GWT livestock system, the above-ground biomass represented 40.9% of the total biomass, below-ground biomass 6.4%, and the litter 52.7%. The livestock system with DTP stored a total of 162.8 Mg C ha<sup>-1</sup>, of which 150.1 Mg C ha<sup>-1</sup> accumulated in the soil (0-30 cm) and 12.7 Mg C ha<sup>-1</sup> in the biomass. While the GWT livestock system stored a total of 116.6 Mg C ha<sup>-1</sup>, of which 111.1 accumulated in the soil and 5.5 Mg C ha<sup>-1</sup> in the biomass. It is concluded that the livestock system with DTP increased 28% of the total carbon reserves compared to the GWT livestock system. However, more studies with a greater diversity of species and at different densities are needed to better understand the contribution of trees on C accumulation in the cattle grazing of the systems of humid tropics of Mexico.</p>	<p>Villanueva López, Gilberto López Santiago, José G. Casanova Lugo, Fernando Martínez Zurimendi, Pablo Jarquín Sánchez, Aarón Bravo Oviedo, Felilpe Aryal, Deb R</p>

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<p><b>The influence of degraded <i>Nothofagus</i> forests with strong anthropic disturbance on soil quality and its recovery with silvopasture in southern Chile</b></p> <p>The increasing demand for timber and non-timber products from native forests in Chile and the cattle grazing has augmented the rate of degradation of these ecosystems. This process results in the need to know which of the dynamic variables are involved in its regulation. Soil quality indicators like soil organic carbon (SOC), soil microbial respiration (SMR), microbial biomass carbon (MBC), potential net N mineralization (N-min), and nitrification (N-NO), soil aggregates, and light fraction (LF), were evaluated at two different depths of the soil in <i>Nothofagus obliqua</i> (deciduous) and mixed <i>N. dombeyi</i> - <i>N. obliqua</i> (evergreen-deciduous) forests, where a 30-ha silvopastoral trial was established, after this evaluation, in early 2016. The SOC, SMR, MBC, N-min and N-NO were significantly higher in the <i>N. obliqua</i> forest than the mixed forest, 8%, 17%, 17%, 40%, 20%, respectively (<math>p &lt; 0.05</math>). The dry weight in soil fractions did not present differences between forest types. C and N contents in the LF (labile, un-decomposed organic matter of plant origin) were higher in the deciduous forest, 9% and 20%, respectively (<math>p &lt; 0.05</math>). Our results suggest that soil quality was favored by the quality of organic matter in the site dominated by deciduous species, which translates into more favorable conditions for the activity of microorganisms, nitrogen dynamic, and C and N content in the light fraction. The intrinsic characteristics of the plant residues associated with higher rates of decomposition, can stimulate the activity of the biota and especially the soil microorganisms, which would lead to higher values of the different indicators evaluated. This novel silvopastoral system will likely help restore the most degraded sites through improvement of the soil quality. This kind of information allows obtaining knowledge of the forest areas and their sustainability, mainly for the planning of long-term, durable silvopastoral practices.</p>	<p>Dube, Francis Alfaro, Marianela Zagal, Erick</p>
<p><b>Comparative assessment of soil health indicators in hardwood silvopasture and treeless pasture</b></p> <p>Silvopasture involves the deliberate integration of trees, livestock, and forages under a common management unit and is perhaps the most common form of agroforestry practiced in the southeastern US. Hardwood trees such as black walnut (<i>Juglans nigra</i>) and honeylocust (<i>Gleditsia triacanthos</i>) have garnered particular interest for use in silvopastures and other temperate agroforestry systems; however, exploration of the ecological or environmental benefits from integrating these species into silvopasture systems is limited. Thus, this study was conducted with an objective to assess soil health indicators in 25-year-old black walnut (BSP) and honeylocust (HSP) silvopastures and compare them with those from adjacent treeless open pasture (OP) systems. Soil samples were collected from 0-10 cm depth and analyzed for soil pH, bulk density (BD), organic matter (OM), soil organic carbon (SOC), carbon and nitrogen fractions, microbial biomass carbon and nitrogen (MBC/MBN), glomalin-related soil protein (GRSP), soil enzyme activity, and microbial community structure. Soil OM concentration was greater in HSP compared to the BSP and OP (<math>p &lt; 0.05</math>). The SOC level was greater in HSP compared to the OP (<math>p &lt; 0.05</math>). Soil MBC was greater (<math>p &lt; 0.05</math>) in BSP than in OP. Silvopasture treatments resulted in greater (<math>p &lt; 0.05</math>) soil MBC compared to the OP. The BSP supported greater (<math>p &lt; 0.05</math>) <math>\beta</math>-glucosidase and urease activities than the HSP and OP treatments, while the <math>\beta</math>-glucosidase activity was higher in HSP compared to OP. Total phospholipid-derived fatty acid (PLFA) and actinomycetes abundance were greater in OP compared to BSP and HSP while the arbuscular mycorrhiza fungi (AMF) abundance was greater in OP than in HSP.</p>	<p>Poudel, Sanjok Bansal, Sangeeta Podder, Swarup Paneru, Bidur Karki, Sangita Fike, John Kumar, Sandeep</p>

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These findings indicate that integration of hardwood tree species such as black walnut and honeylocust can potentially improve soil carbon and nitrogen fractions in soil along with altering soil microbial and enzyme activity in soil over time.	
<p><b>Soil biological indicators are more sensitive to differences in shade tree species arrangements in a young cocoa (<i>Theobroma cacao</i> L.) agroforestry trial</b></p> <p>Agroforests can contribute to the restoration and maintenance of soil quality and productivity in cocoa production systems. The purpose of this study was quantify the effect of different agroforests arrangements on soil quality and its relation to cocoa productivity. Field sampling took place in October 2019 in a five-year-old experimental cocoa trial located in the Amazon region of northeastern Ecuador. The trial consists of five agroforestry system treatments: “monoculture” (cacao only), “timber” (cacao with the leguminous timber tree <i>Cedrelinga cateniformis</i> Ducke), “fruit” (cacao with peach palm - <i>Bactris gasipaes</i>), “N-fix” (cacao with the leguminous tree <i>Erythrina velutina</i> Wild) and “mixed” (cacao with <i>Cedrelinga cateniformis</i> Ducke + <i>Erythrina velutina</i> Wild trees). This study focused on the part of the trial that was managed organically with low levels of inputs. An integrated soil-litter-leaf sampling strategy was applied, within each plot samples were taken at two different distances from the shade trees (~2m and ~6m) or in the center of the plots. Litter characteristics included micro- and macronutrients, Cd content, total polyphenol content, lignin content and potential respiration. Cocoa leaf samples were tested for Cd, micro- and macronutrient content. Soil quality indicators included potential soil respiration, macrofauna diversity, abundance and richness, micro and macro nutrients, pH, CEC, Cd, Bulk density, and aggregate stability. Yield data was provided by Instituto Nacional de Investigaciones Agropecuarias (INIA), the monitoring institution. Main findings revealed that early impacts, within 5 years, of agroforestry implementation were primarily detected by biological soil indicators (e.g. earthworm abundance and microbial respiration). Agroforestry arrangements did not impact yield in this production trial. Distance had overall a minor influence on the results. It is important to consider which shade species to plant in agroforestry systems, so to manage impacts on understory crops and soils.</p>	<p>Visscher, Anna Maria Chavez, Eduardo Pulleman, Mirjam</p>
<p><b>Site condition rather than land use type has greater influences on soil chemical properties and abundance and diversity of arbuscular mycorrhiza</b></p> <p>Arbuscular mycorrhiza fungi (AMF) is widely recognised as a vital component of soil fertility in tropical agroecosystems. Majority of studies have shown the importance of AMF in agroecosystems but few have shown how AMF communities are influenced by vegetation type and soil chemical properties. The objective of this study was to determine the influence of land use types and soil chemical properties on the abundance of AMF spores and diversity. Three sites were selected from an ongoing program: Kenya Cereal Enhancement Programme Climate Resilient Agricultural Livelihoods (KCEP-CRAL). The sites were Kubo South located in Kwale County, Muminji in Embu County, and Thange in Makueni County. These sites were identified using the land degradation surveillance framework (LDSF) from both cultivated and non-cultivated plots. Land use types included bushland, grassland, cropland and shrubland. It was hypothesized that AMF and soil chemical properties would be greatly influenced by type of land use and the condition of the site. The various land use types showed minimal influence differences for instance average total C content was significantly higher in Muminji and Thange site (8.2 and 13.4 g kg<sup>-1</sup> respectively) compared to Kubo South (4.7 g kg<sup>-1</sup>), whereas total N content was low in Muminji (0.1 g kg<sup>-1</sup>) compared to Kubo South (0.5 g kg<sup>-1</sup>) and Thange (1.1g kg<sup>-1</sup>). Greater abundance of AMF spores were</p>	<p>Mwangi, Lukelysia Winowiecki, Leigh Kamau, Solomon</p>

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recorded in soil from Muminji site (385 spores kg <sup>-1</sup> soil) followed by Kubo south (217 spores kg <sup>-1</sup> soil) and lowest in Thange (67 spores kg <sup>-1</sup> soil). Nonetheless, vegetation type had little influence on soil chemical properties and on abundance and distribution of AMF spore's count. Consequently, these results can be used to support the notion of options by context approach which is a paradigm shift in agronomy.	
<p><b>Root distributions and traits in a tropical agroforestry parkland dominated by <i>Faidherbia albida</i>: potential impacts on soil C and nutrients stocks?</b></p> <p>In agroforestry systems, the associated plants can induce an heterogeneity of the entries of C originating from roots according to the distance to the tree and depth. The aims of this study were (i) to analyse the root strategies for both perennial (<i>Faidherbia albida</i>) and annual (pearl millet) species, (ii) to quantify the root C inputs to the soil and (iii) to link the root systems to soil properties. Crop aerial biomass was higher under the trees than further away, whereas the crop root biomass was equivalent and concentrated at 0-10 cm of depth. On the contrary, <i>Faidherbia</i> roots were concentrated in soil layers below 100 cm, at both locations (under and further away from the trees). Root traits such as length and diameter followed exponential decay with increasing depth. <i>Faidherbia</i> roots had higher C and N content than pearl millet and for both species, root N content increased with increasing depth. The topsoil was richer in C and N under than further away from the trees, but it was not true below the depth of 10 cm. The higher soil C and N contents under the trees might mainly be due to the tree aerial litter inputs rather than to the root inputs as (i) no difference in the root systems was noteworthy according to the location and as (ii) differences in soil quality occurred only in topsoil. Tree roots occupied deeper soil layers than the crop, probably as a response to the long period of cohabitation in this site. <i>Faidherbia</i> would compensate the lack of nutrients in deep soil layers by extending its investment area. The complementarity of the perennial and annual root systems ensured an efficient use of soil resources and significant carbon inputs below 100 cm of depth.</p>	<p>Siegwart, Lorène Bertrand, Isabelle Jourdan, Christophe</p>
<p><b>Root litter decomposition in a sub-Saharan agroforestry parkland dominated by <i>Faidherbia albida</i></b></p> <p>In agroecosystems, the decomposition of fine roots contributes to soil organic carbon stocks and may impact soil fertility, particularly in poor soils, such as those encountered in sub-Saharan regions. The aim of our study was to measure the decomposition rate of root litter from annual and perennial species according to soil depth and location under or far from trees in a sub-Saharan agroforestry parkland dominated by <i>Faidherbia albida</i>. Soil characteristics under and far from the trees were analysed from topsoil to 200 cm depth. <i>Faidherbia</i> tree, pearl millet and cowpea root litter samples were buried in litterbags for 15 months at 20, 40, 90 and 180 cm depths and soil moisture was monitored across the soil profiles. Root litter decomposition was mainly impacted by soil moisture and thus soil depth, with the main differences among plant species and depths observed during the first 1.5 months of decomposition. Due to their chemical recalcitrance, <i>Faidherbia</i> decomposed more slowly (<math>36 \pm 12\%</math> remaining mass after 15 months of decomposition) than cowpea and pearl millet roots (<math>23 \pm 7\%</math> and <math>29 \pm 11\%</math> respectively), while both annual plants exhibiting lower rates of decomposition at depth than in the surface. Both <i>Faidherbia</i> fine roots and millet aerial biomass contributed slightly to higher stocks of C under the tree (<math>7761 \pm 346</math> g m<sup>2</sup>) than far from it (<math>5425 \pm 558</math> g m<sup>2</sup>) and from 0 cm down to 200 cm depth. Due to their slow root decomposition rates at depth and the increase in crop production in their</p>	<p>Siegwart, Lorène Bertrand, Isabelle Jourdan, Christophe</p>

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vicinity, Faidherbia trees play a crucial role in increasing belowground carbon storage in semiarid Sahelian parklands.	
<b>Quantification of shelterbelt effects in Danish agroforestry systems</b> Agroforestry systems are gaining increasing attention due to their potential for climate change mitigation and adaptation within food production systems (IPCC, 2019). Research from across the temperate region has proven several benefits to be increased from agroforestry production compared to conventional agriculture, including: yield (Lehmann et al., 2020), carbon (C) sequestration (De Stefano & Jacobsen, 2018), water and nutrient cycling (Quinkenstein et al., 2009; Zhu et al., 2019), and biodiversity (Bentrup et al., 2019). However, the extent of agroforestry systems are still limited (Den Herder et al., 2017), and the abovementioned benefits has yet to be measured under Danish conditions. Therefore, this study aims to quantify the effect of agroforestry at two sites in Denmark, respectively a grain and a grass field, with a shelterbelt of mixed woody crops located across the centre of the field. The impact will be assessed for a range of aspects: crop and wood production, C sequestration, nitrogen (N) leaching, and soil organism biodiversity and related potential greenhouse gas emission. Data is being collected from within the shelterbelt, and in the field at 2, 7, 15 and 25 metres from the edge of the shelterbelt, to assess how far into the field the potential advantages or disadvantages of the trees reach. Samples are collected from the crop biomass harvested annually over three growing seasons, soil water sampled on a monthly basis, shelterbelt biomass, and soil. The study runs from 2021-2024, over a three-year period. Preliminary results on crop production, C and N content in soil and crop, and N in soil water, indicate a large effect of the shelterbelts. The goal of the study is to contribute to the assessment of the agroforestry system potential in Denmark, and provide a robust research-based foundation to optimise the design of temperate agroforestry systems going forward.	Lehmann, Lisa
<b>Agroforestry based on legume trees to improve banana cropping ecosystem services provision</b> Agroforestry is a promising lead to face environmental and societal emerging challenges faced by tropical agroecosystems. This stake is especially high in West Indies, where global changes consequences are already impacting banana cropping systems. Yet, agroforestry is not well known in these territories, and needs more research before being advised to the farmers. In this context, CIRAD set up an experimental site in 2018 comparing three banana cropping systems: (i) a conventional system, mirroring the average practices in Martinican banana systems, (ii) a bio-intensive system, where synthetic inputs are replaced by organic ones, and (iii) a bio-diversified system, associating organic inputs with a complementary crop (cocoa) and legume service-trees ( <i>Inga Ingoides</i> and <i>Indigofera zollingeriana</i> ). The following ecosystem services and disservices were assessed after four years: C storage, N provision and competition, soil structure maintenance, and weevil and plant-feeding nematodes regulation, in parallel to crop yield. The three systems exhibited contrasting services provision. In 2021, banana yield was the highest in the conventional system thanks to shorter production cycles, and the lowest in the bio-diversified system due to lower banana plantation density. Nonetheless, the conventional system faced higher weevil pressure compared to the organic systems, likely due to the lower diversity found in this system. On the other hand, the organic systems faced higher competition for N yet higher levels of C restitution due to their mechanical management of the inter-row weeds. This effect was in part counterbalanced in the bio-diversified system by the presence of legume trees, which led to a	Sauvadet, Marie Prochasson, Alice Normand, Loïc Dorey, Elodie Dorel, Marc Achard, Raphaël Tixier, Philippe Rosalie, Elisabeth Gervais, Laurent Guillermet, Claire Coulis, Mathieu



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significant enrichment of soil C and above all soil organic N (+15% and +11% increase compared to the conventional system, respectively). Overall, the services trade-offs suggest a better sustainability of the agroforestry system due to a fast increase of soil quality, that needs to be confirmed by longer-term analyses.	
<p><b>Deciphering soil organic carbon content and its potential regulators in homestead agroforestry systems of northern Bangladesh</b></p> <p>Homegarden agroforestry system is a common practice in South Asia and had the potential to sequester carbon in both above and below-ground biomass. Studies explicitly identify the aboveground carbon content and its regulators; however, little is known about the soil organic carbon content in the homegarden and their potential regulators in the northern part of Bangladesh. Therefore, this study was conducted to decipher soil organic carbon content in the homegardens of northern Bangladesh and also to identify the potential regulators of soil organic carbon. This study was conducted in Dinajpur sadar (sub-district) of Dinajpur district. A total of 64 homegardens were sampled; structural data and soil samples were collected from the homegardens. A total of 27 species were found in the homegardens, tree density ranged from 10-28/100m<sup>2</sup> and the species richness (Margalef index) was 1-4.75. The highest soil organic carbon (SOC) was found in a larger size (1.69%) homegarden followed by in medium (1.46%) and smaller size (0.688%) homegardens. We applied structural equation modeling (SEM) to test the direct and indirect effect of stand structural diversity on SOC. The SEM accounted for 62% variation in SOC. Homegarden size had the strong direct (<math>\beta = 0.45</math>) effect on SOC followed by diameter at breast height (DBH) diversity (<math>\beta = 0.28</math>), species richness (<math>\beta = 0.24</math>) and height diversity (<math>\beta = 0.21</math>). Our results suggest that a larger size homegarden might store the maximum amount of carbon due to the higher richness of the species. Moreover, higher species richness promotes maximum utilization of resources resulted in variation of structural diversity which positively influenced SOC. This study showed species-rich homegardens with a high density of tree species can sequester a higher amount of carbon in soil and might contribute to reducing the pessimistic effect of climate change.</p>	Hanif, Md Abu Islam, Md Saiful
<p><b>Agroforestry for soil macro-fauna conservation and soil fertility enhancement: Empirical evidence from cocoa-based agroforestry systems in Cameroon</b></p> <p>Soil infertility is a major problem affecting agricultural production and productivity in many parts of the world today. In Cameroon, the situation is dire owing to poor agricultural practices and the ever present menace of climate change. Thus, this study was carried out to assess the contribution of soil macro-fauna to soil fertility improvement in cocoa-based agroforestry systems (CBAFS) in the littoral region of Cameroon. Socio-economic, physico-chemical and biophysical data was collected. Collected data was coded and imputed into Excel, SPSS and R software for descriptive and inferential statistical analysis. Earth worms (100%), ants (100%), termites (70%), millipedes (50%), centipedes (50%), and snails (60%) are identified by cocoa farmers as the main soil macro-fauna in CBAFS. Based on biophysical data, the main soil macro-fauna species in CBAFS are termites, ants, earth worms, woodlice and snails. Trees species diversity in CBAFS is relatively high (Shannon-Wiener index &gt; 2). The main types of tree species integrated by cocoa farmers in CBAFS are fruit trees (100%), fuelwood trees (70%), trees for shade (52.7%) and trees for building materials (40%). A cause-effect relationship (<math>p &lt; 0.05</math>) exists between the level of tree diversity and density in CBAFS and the level of soil macro-fauna diversity and density. Soils under CBAFS are dominated by ferralsols and gleysols having physico-chemical characteristics that portray high fertility.</p>	Tsufac, Azembouh Roshinus Yerima, Bernard Palmer Kfuban Awazi, Nyong Princely Enang, Roger Kogge

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<p>Most cocoa farmers (&gt; 50%) observed that earth worms, ants, termites contributed highly to soil fertility improvement in CBAFS. Earth worms, ants, termites, beetles, snails and slugs were the main soil macro-fauna having a direct causal relationship (<math>p &lt; 0.05</math>) with soil fertility improvement in CBAFS. Soil analysis equally reveals the presence of soil macro-fauna remains in the upper layers of the soil which accounts for the relative high fertility levels in the soil. More action should be taken by policy makers to ensure the sustainability of soil macro-fauna in CBAFS as this will go a long way to maintain and enhance soil fertility.</p>	
<p><b>Unravelling sustainable intensification in oil-palm agroforestry on Adja plateau, Benin</b></p> <p>On Adja plateau, Benin, landowners evict tenants to replenish soil fertility through oil-palm fallowing. As a reaction, tenants use farmyard manure and mineral fertiliser, arguing that these practices restore soil fertility, allowing them to pursue land cropping. There is little information available on the impacts of these management practices on soil fertility and land productivity, although this information is an essential input for making recommendations about how to lessen land conflicts and improve the sustainability of land-management systems. This study used a synchronic approach, selecting 12 farmers' fields in villages typical of the region, eight and four of which, respectively, represent tenants' (cropping fields) and landowners' (fallow) soil fertility management strategies. An experimental plan was designed, combining different doses of farmyard manure and inorganic fertilisation to assess maize yields and soil fertility in cropped fields compared with fallows. The results showed no significant differences between treatments on cropped fields and fallows regarding N, C, and C: N. However, soil P and K were higher in the treated plots than in the fallows. Maize grain yields under farmyard manure application were better than grain yields under mineral fertiliser alone. In addition, a double dose of farmyard manure was revealed to exceed the mineral fertiliser effect alone. Fertiliser recommendations are provided for tenants' maize production, and trade-offs between sustainability and intensification are discussed.</p>	Yemadje, Rolland
<p><b>Long-term and depth importance to soil carbon analysis in Agroforestry Systems</b></p> <p>Soil fertility is a major issue in the tropics and to its ecosystem functions maintenance and/or restoration. Regarding to soil carbon it is important to detach that only long-term management practices have influence over this soil attribute, mostly if greater soil depths are addressed. One problem that major restoration projects do before implementing agroforestry systems in degraded areas is to measure soil fertility only up to 40 cm, not giving much importance to the pedological aspects related to it. The objective of this work was to elucidate the soil variability in relation to soil carbon that agroforestry areas recently implemented may or may not have from the mean regional values observed in the RADAM Brazil project in the Northeast Amazon. Organic Carbon (CO) results from thirteen agroforestry areas were compared to the mean values from all results obtained and gathered in the Project RADAM - Radar in the Amazon, through geoprocessing tools using ArcGIS software, using interpolation in a raster surface ranging the area with the results points using an inverse distance weighted (IDW) technique. This interpolated values in the depth of 0 to 20 cm and 20 to 40 cm were compared to the results of soil carbon obtained in the georeferenced agroforestry areas. Results show that soil carbon content in upper layers are higher in both cases, agroforestry systems (<math>CO_{mean0-20} = 3.09 \text{ dag dm}^{-3}</math>/<math>CO_{mean20-40} = 1.72 \text{ dag dm}^{-3}</math>) and RADAM profiles (<math>CO_{mean0-20} = 1.2 \text{ dag dm}^{-3}</math>/<math>CO_{mean20-40} = 0.66 \text{ dag dm}^{-3}</math>), what was expected. In comparison to the</p>	Meier, Martin Amaral, Jimi Veloso, Gustavo Carvalho Gomes, Lucas Souza, Saulo Marques, Henrique Miccolis, Andrew



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<p>differences among the means, RADAM values did vary less than agroforestry results, according to skewness and kurtosis analysis. The difference in percentage of CO were 160% higher in both depths comparing agroforestry systems to the RADAM mean results. Agroforestry is a promising strategy to enhance soil carbon using the right management.</p>	
<p><b>Biochar additions as a preventive measure to reduce the ill effects of excess phosphorus application in agroforestry systems</b></p> <p>Application of high rates of nutrient-rich manures, as in silvopastoral systems of Florida, causes the serious environmental problem of eutrophication of water bodies that receive phosphorus (P) and nitrogen (N) via runoff and/or leaching from such soils. Manures derived from animal sources such as poultry and cattle result in continuous P loss from the soil when in contact with water. Conversion of such manures and biosolids into biochar offers a preventive and remedial measure to address this problem. The conversions will also reduce the volume of material and thereby its off-site transportation cost. Our analysis of biochars from poultry litter (PLB), biosolids from two different processing units (Biosolids1 and Biosolids2), and hardwoods (HWB) showed variations in pH, total P (TP), total N (TKN), total carbon (TC), and other nutrients (potassium, calcium, and magnesium) in a soil test solution such as the Mehlich 3-extract. The high surface area of biochar will help retain added P and would, therefore, be important for sandy soils where P is readily lost from the soil, as well as for more retentive soils where P availability is a major problem. Addition of a wood-based biochar with minimal P concentrations will assist in holding on to excess P and minimize P loss from a heavy P-impacted soil. Simultaneously, the biochar will increase the carbon in soils and contribute to long-term C storage, serving as a soil-based greenhouse gas mitigation strategy. Phosphorus sources from animal manures could be mixed with biochars in accordance with local conditions of soil types as well as feedstock availability for conversion to biochar. Biochar additions will serve both as a preventive and remedial measure for nutrient (especially P) loss from the soil. The high water-holding capacity of biochar could be an added advantage in arid and semiarid lands.</p>	<p>Nair, Vimala Nair, Pk Ramachandran Freitas, Andressa</p>
<p><b>Biofertilizers for perennial grass biomass crops and the environment</b></p> <p>The acreage of herbaceous perennial biomass crops switchgrass (<i>Panicum virgatum</i>) and miscanthus (<i>Miscanthus</i> spp.) is increasing on marginal agricultural land in Ontario. This should ensure a supply of renewable feedstocks to industries such as bioenergy, biomaterials, livestock feed and bedding, and garden mulch. Growers have expressed interest in enhancing the sustainability of their biomass production systems by reducing the use of chemical fertilizers. Therefore, a two-year field experiment testing the agronomic and environmental impacts of four commercially available biofertilizers (JumpStart®, MYKE® Pro / AGTIV®, Optimyc + MooR, and LysteGro) along with a typical nitrogen fertilizer treatment and a control. Biomass yield, soil health (qPCR for bacterial and fungal [16S and 18S] genes, soil respiration, spring earthworm abundance) and fertility (soil availability and plant tissue concentration of nitrogen, phosphorus, potassium, magnesium, and calcium) were measured. Chemical nitrogen significantly enhanced switchgrass yield after two years; however, the biofertilizer AGTIV® significantly enhanced miscanthus yield. The 2019 soil incubation experiment clearly significant release of macronutrients (nitrogen, phosphorus, and potassium) by all fertilizers significantly compared to the control. AGTIV® and Optimyc + MooR also significantly increased 16S and 18S gene abundance in the top 10 cm of soil under switchgrass cultivation in 2020, demonstrating their ability to enhance soil</p>	<p>Hasenack, Sarah Thevathasan, Naresh Dunfield, Kari Voroney, Paul</p>

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microbial abundance. This study provides novel insights into the agronomic and environmental benefits of biofertilizers for biomass crops in Ontario, and the findings suggest that biomass growers can use certain commercially available biofertilizers for sustainable biomass crop production. Additional costs of biofertilizer use should be subsidized by government policies to enhance adoption by biomass growers.	
<b>B. Transitioning to Better Water Balance and Light Valorization</b>	
<p><b>Trees both reduce and increase water availability depending upon the distance from the rows in a tree-based intercropping system</b></p> <p>Due to global changes, agricultural productivity in Quebec could soon be affected by warmer temperatures and more erratic summer precipitation, increasing the probability of water stress. Tree-based intercropping (TBI) systems might be a promising path towards more resilient agroecosystems. We aimed to characterize the different effects of trees on microclimate conditions, specifically, whether or not water availability would improve in a 10-year-old TBI system established in southern Quebec, Canada. High-value hardwood species and hybrid poplars were planted alternately every 5 m along each row, which were planted 40 m apart resulting in a density of 50 stems ha<sup>-1</sup>. During the summer of 2021, weather stations were deployed at 4, 12 and 20 m downwind from a tree row and in an agricultural control without trees (replicated in two blocks). They continuously measured wind speed, light availability, soil temperature and moisture. The wind speed was slower in the TBI plots compared to controls. Within the TBI system, wind speed decreased with increasing the distance from the tree row. As expected, shading was more important closer to a row. Accordingly, soil temperature decreased closer to a row and was lower in the TBI system compared to controls. The 4-m soils were the driest and the 12-m soils the most humid. The 20-m and control soils had intermediate and equivalent values. While preliminary, these results show that water availability was reduced closest to the trees, even though lower soil temperature and shading probably reduced evapotranspiration. Therefore, rainfall interception and water uptake by trees were likely more influential at 4 m. However, increased soil moisture at 12 m indicates that reduced evapotranspiration could become predominant in the rest of the system, probably helped by reduced wind. Measurements at a finer scale might be necessary to assess the overall effect of trees on water availability.</p>	<p>Hebert, Eve-Marie Martin Guay, Marc-Olivier Maheu, Audrey Rivest, David</p>
<p><b>Benefits of agroforestry for nitrogen cycle in temperate regions. A case study examining the context of dairy farming in the Brittany region (France)</b></p> <p>Excess of reactive nitrogen threatens our ecosystems through modification of soil, air, water quality and modification of biodiversity. Nitrogen pollution is then still of a major concern, even greater than carbon through its complex effects on ecosystems. Nitrogen losses to water streams, are highly concerning for territories that are specialized in livestock farming. In a near future, such losses are expected to increase under extreme events as a consequence of climate change. According to the “safety net hypothesis”, tree-crop association in livestock areas is expected to prevent nitrogen losses while providing other ecosystem services and sustaining agroecosystem productivity. However, the integration of agroforestry with livestock production is limited in temperate regions, and it urges to provide an assessment of its potential benefits. Started by mid-November 2021, we aim to explore the potential benefits of agroforestry design or enhancing the nitrogen</p>	<p>Mettauer, Romane Godinot, Olivier Le Cadre, Edith</p>

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cycle within dairy farming systems in the North West of France. We hypothesize that presence of trees or hedgerows, as agroforestry design, alters the microbial nitrification and favor water drainage within plots, thus limiting nitrogen losses to the environment and specially to water streams. In the present application, we will present the results of a laboratory experiment devoted to estimation of potential nitrification, through nitrate release, under different regimes of rain that are expected to occur in near future in this region. Soil samples will be collected within plots presenting alley cropping agroforestry or hedgerows. The results will be analyzed using structural equation modelling in order to understand measurements and explanatory factors. In a second step, the results will be re-interpreted at the farm's scale and the territory's scale, with a participative approach to balance nitrogen losses with other ecosystems services.	
<b>Mitigation of Nitrogen leaching with agroforestry: an assessment in various soil and climate conditions of the Rhône River watershed in France with the Hi-sAFé model</b> Nitrogen leaching from cropped areas is a concern as it contributes to groundwater contamination, and underutilized soil fertility. The intensity of leaching is affected by soil type and structure, the amount of water used by the plants/crops; and the quantity of nitrate present in the soil. High levels of nitrate leaching are frequent in monocropping during heavy rain seasons, especially when these rains occur during warm seasons that favour mineralization of soil organic matter. This concern is high in the Rhône River watershed in France, where heavy Mediterranean type rains occur in early autumn. We used the Hi-sAFé biophysical model to assess the impact of agroforestry trees in alley-cropping on Nitrate leaching for different soil and climate conditions of the Rhône River watershed. The model predicts the impact of trees on both the water and the nitrogen dynamics in the soil, taking into consideration the 3D structure of the tree root system, and the phenology of the trees. Simulations were performed for the whole tree life cycle (40 years long) in order to detect the minimum size of the trees that will impact the nitrate leaching process. Complex patterns of nitrate leaching are evidenced, but common trends are as follows: AF systems surprisingly do not modify significantly the total annual water drainage, reduce soil evaporation, reduce water run-off, and substantially reduce Nitrate leaching in most cases (Figure 1). The model allows to identify mechanisms that explain the site by site differences in nitrate leaching.	Dupraz, Christian Gendron, Thomas Lecomte, Isabelle Gosme, Marie
<b>Wild lupins as a novel crop in a silvoarable system</b> Uniformity in agriculture exposes food systems to vulnerability. We are exploring two dimensions of agricultural diversification: 1) increasing diversity of cultivated species by recruiting native plants as novel crops; 2) breaking structural uniformity by using trees and annuals in the same space. Specifically, Shade tolerance is an emerging issue in the research of agroforestry and agri-voltaic systems. We are examining agronomic and nutritional aspects of recruiting <i>Lupinus pilosus</i> , native to Israel and the Mediterranean region, as a novel protein crop in a silvoarable system. The objective of our research is to examine wild populations of <i>L. pilosus</i> in a silvoarable system. We aim at studying shade tolerance of <i>L. pilosus</i> as a novel protein crop, intercropped in an olive orchard. We are studying <i>L. pilosus</i> development under five shade treatments: 0%, 30%, 60%, 90%, and olive tree shade (Fig. 1). In a common garden experiment, we compare the performance of 10 wild populations, with 20 individuals per population in each treatment. Preliminary results show, that <i>L. pilosus</i> has a promising agronomic potential to produce protein-rich seed yield. In addition, we are studying the nutritional profile	Ben-Simchon, Eyal Shelef, Oren

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of the seeds, and alkaloid content, that still restricts its direct use. We expect the results of the current experiment by the end of June 2022. Developing agroforestry systems will support the important goal of diversifying agriculture to enhance resilience in the face of projected changes. This novel agroforestry system design can foster economic and sustainable growth, by the diversification of crops and field heterogeneity. This project is funded by GIF Research Grant No. I-1540-500.15/2021 "Sustainable agro-system: wild lupins as a novel crop in a silvoarable system".	
<b>Agroforestry buffers on nitrogen and phosphorus concentration in shallow groundwater on a hillslope</b> Elevated nitrogen (N) and phosphorus (P) levels in groundwater can produce eutrophication and harm human health. Therefore, low-cost strategies that extract nutrients from groundwater are essential to address water pollution. Vegetative covers that interact with the water table are effective natural systems that reduce nutrients before reaching surface water bodies. This study evaluates the effects of agroforestry buffers (AB) [cottonwood ( <i>Populus deltoides</i> Bortr. ex Marsh.)] and grass buffers (GB) [Tall fescue <i>Schedonorus phoenix</i> (Scop.) Holub, Red clover ( <i>Trifolium pretense</i> L.), and Lespedeza ( <i>Lespedeza Michx</i> )] on nitrogen and phosphorus in groundwater. The experiment consisted of two watersheds with AB and GB treatments, respectively, under grazing on a hillslope. Each watershed was instrumented with three wells representing summit, backslope, and foot-slope positions. The wells in the foot-slope position were located downgradient of the AB and GB. The two treated watersheds were monitored from November 2019 to November 2021. Dissolved nitrogen (DN) and total nitrogen (TN) concentrations after the AB were reduced by 99% and 87%, compared to the concentrations in the summit well. Similarly, DN and TN concentrations after the GB were reduced by 96% and 61%, compared to the summit well. No P reductions were found in this experiment. After passing through the AB, the mean concentration of DN and TN in groundwater were 0.06 and 1.72 mg L <sup>-1</sup> , respectively, while in the GB, they were 0.08 and 1.49 mg L <sup>-1</sup> , respectively. Lower concentrations of DN and TN were observed after precipitation events and during the summer months. These decreases can be attributed to plant uptake and denitrification in the buffer zone. The AB showed greater reductions on DN and TN than the GB treatment. This study shows that tree and grass buffers in the proximity of the water table considerably decrease TN and DN concentrations in groundwater by taking up N and enhancing N-reducing processes.	Salceda, Miguel Udawatta, Ranjith Anderson, Stephen Mendis, Sidath
<b>Developing A Novel Spore-based Biocatalyst Enzyme Delivery System for Remediation of Atrazine in Riparian Buffer Systems</b> Background. Atrazine (ATR) is an endocrine disruptor causing birth defects and reproductive tumors in amphibians and humans. Owing to agricultural activities, atrazine contaminates soil, groundwater and drinking water sources across the U.S. Recent studies have suggested that the vegetative riparian buffer systems could effectively remove the atrazine through physical trapping and enhanced rhizodegradation. The introduction of other bioagents that could rapidly enhance the degradation the atrazine and its degradation products will significantly facilitate the removal process. Objective. The objective of the study is to remediate atrazine to non-toxic metabolites using enzyme-bearing spores. Method. A <i>Bacillus thuringiensis</i> spore platform system that can express a high density of enzymes has been successfully developed at University of Missouri. The system was utilized to display six enzymes, Atz(A-F) found in the atrazine	Hsu, Shu-Yu Hsieh, Hsin-Yeh Stewart, George Lin, Chung-Ho

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degradation pathway in <i>Pseudomonas</i> sp. strain ADP, on its surface using by cloning techniques. The enzymatic kinetics of individual Atz-enzyme-bearing spores were characterized. The levels of ATR and its metabolites were determined by liquid chromatography coupled with tandem mass spectrometry. Results. Our results showed the AtzA-bearing spores were stable with a shelf-life longer than four years. They degraded 80% of applied ATR to non-toxic and less mobile metabolites hydroxyatrazine (HA) in soils within 48 hours. AtzA-bearing spores demonstrated better stability in the soil compared to the free AtzA enzyme in the runoff experiment. Furthermore, the AtzB-bearing spores degraded the HA to N-isopropylammelide (NiPA) in water. The mixture of AtzA-bearing and AtzB-bearing spores was applied in the remediation of ATR in the water and this multi-enzyme system has successfully converted 90% ATR to NiPA after 96 hours of incubation. Discussion and Conclusion. With the success of this study, the spore-based display system can be incorporated into agroforestry riparian buffer systems to improve the efficiency of removing the atrazine and other persistent organic pollutants.	

### C. Transitioning to Biodiversity

<p><b>Représentations sociales de la biodiversité en agroenvironnement au Québec</b></p> <p>Le rapport que les acteurs en agriculture entretiennent avec la biodiversité influence la gouvernance en agroenvironnement. Toutefois, la pluralité dimensionnelle du concept de biodiversité en lui-même est méconnue, d'autant plus que la biodiversité est difficilement quantifiable et saisissable dans son ensemble. Par conséquent, les représentations sociales que les parties prenantes en agriculture se font de la biodiversité méritent d'être étudiées afin de comprendre les orientations données à des projets ou à des politiques à caractères agroenvironnementaux. Dans une visée exploratoire, l'objectif de cette étude est d'effectuer une typologie des représentations que les acteurs de projets collectifs en agroenvironnement au Québec se font de la biodiversité. Les parties prenantes d'intérêts sont des producteurs et conseillers agricoles, des autorités locales, des chercheurs ainsi que des représentants d'organismes de bassin versant. Afin d'effectuer une analyse mixte, les collectes de données se font par des cartes mentales, des entretiens individuels semi-dirigés ainsi que par la méthodologie Q. Ces méthodes permettent d'approfondir les perceptions en lien avec la gestion de la biodiversité en agriculture ainsi que de se familiariser avec les dimensions sémantiques associées au mot biodiversité dans le milieu agricole. Essentiellement, l'étude cherche à identifier les différentes représentations cognitives associées à la biodiversité dans le milieu agricole au Québec. Il est important de reconnaître la pluralité dimensionnelle des représentations de la biodiversité afin de l'intégrer en gouvernance agroenvironnementale. En effet, les résultats de la typologie escomptée sont un atout considérable pour accompagner les réflexions municipales ou gouvernementales visant à favoriser les pratiques agricoles soucieuses de l'environnement, tout comme celles en lien avec l'agroforesterie (implantation de bandes riveraines, de haies brise-vent, etc.) ou autre modèle agricole conciliant agriculture et biodiversité.</p>	<p>Saydeh, Marie</p>
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<p><b>Domestication of <i>Gnetum africanum</i> Welw. (<i>Gnetaceae</i>): Assessment of growth and development parameters in the ICRAF genebank in Mbalmayo</b></p> <p><i>Gnetum africanum</i> Welw, a vegetable commonly referred as ‘wild spinach’ (Figure 1), is a priority species in West and Central Africa. The landscape degradation, ever-increasing demand coupled with the bad harvesting techniques have led to the depletion of the resource in its geographical range such the way that the International Union for the Nature Conservation (IUCN) has red listed in the category of near threatened (NT) species. Therefore, urgent conservation measures were undertaken by different stakeholders including ICRAF. The current study was conducted in ICRAF’s genebank in Mbalmayo (Figure 2), with the objectives of evaluating the effect of provenance and accession on the growth and development parameters in view of promoting its domestication for conservation and use. Indeed, in 2012 four provenances (Boumnyebel, Mbalmayo, Mfou and Lékié-Assi) were planted by repeating in 03 plots. For each provenance there are 29 accessions per replicate, which gives 116 accessions for a plot and a total of 348 lianas. The studied parameters are liana length, number of main branches, number of secondary branches, number of leaves, collar diameter, and leaf dry weight. Data collection was carried-out each year from 2012 for the first four parameters while in the year 2021, evaluation was done for the last two parameters. The multivariate analysis of the generalized linear model was carried out, to determine the statistical differences between the provenances and accessions, with a probability threshold of 5%. Results in 2021 shows that provenance has no significant (<math>P &gt; 0.05</math>) effect on the various parameters studied. Accession has significant (<math>P &lt; 0.05</math>) effect on the number of main and secondary branches, the dry weight, number of leaves and the collar diameter. GA/MFOU/09 is the best accession for leaf dry weight (<math>1.67 \pm 0.58</math> g i.e. 17 kgs/ha). The study added value to the domestication for conservation of <i>G. africanum</i> by; in one hand describing its variation within the genebank and, in second hand identifying “plus lianas” that could be source of planting materials for farmers.</p>	<p>Tsobeng, Alain Calice Temgoua, Lucie Félicité Tassemo Temfack, Roxy Caspa, Rose Muchugi, Alice Kang'ethe, Simon Degrande, Ann Ramni, Jamnadass Tchoundjeu, Zacharie</p>
<p><b>Analyzing the contribution of coffee and cocoa based agroforestry systems to the conservation of biodiversity in Cameroon</b></p> <p>The 1980s were marked by a coffee and cocoa crisis following the fall in world prices. To cope with this, production systems have evolved towards crop diversification and farmers in Cameroon are growing cocoa and coffee in agroforestry systems by conserving or introducing useful woody species. Our study was carried out in the littoral, East and West regions with the objective of analyzing the contribution of cocoa and coffee agroforestry systems (AFS) to biodiversity conservation. Floristic inventories were carried out in agroforestry plots and surveys were conducted among farmers to identify the origin, and the uses of trees. In agroforestry systems, the richness of woody species was higher in the Eastern region (71 species) than in the Littoral (27 species) and Western regions (30 species). In the East, the AFS were also more diverse (Shannon diversity index <math>H' \geq 3</math>), with a high proportion of trees retained at the time of plantation creation (over 90%). In the Littoral and West regions, the proportion of introduced trees is the most important (over 70%). In these two regions, the low diversity of AFS (<math>H' &lt; 3</math>) characterizes the dominance of a group of species, most often introduced and fruits species (<i>Cola acuminata</i>, <i>Elaeis guineensis</i>, <i>Carica papaya</i>, <i>Persea americana</i> and <i>Dacryodes edulis</i>). These associated trees are mostly multi-purpose trees that provide food, medicine, wood and contribute to the improvement of soil fertility while providing shade to cocoa or coffee. A large number of species with a conservation issue according to the status of the IUCN</p>	<p>Temgoua, Lucie Félicité Boucheke, Robert Kévin Nkwelle, Junior Djeuni, Romuald Momo Solefack, Marie Caroline</p>

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red list have been identified in coffee and cocoa AFS. Strategies to improve the coffee and cocoa based AFS must take into account the tree species needed by farmers and support these farmers in their search for the best trade-offs between coffee/cocoa production and biodiversity conservation.	
<b>Study on functional biodiversity between rows and at the edges of experimental nut groves in the Lower St. Lawrence region of Canada</b> As part of a large-scale research project to develop the practice of hazelnut cultivation in northern climates, 23 nut groves were planted in the Lower St. Lawrence region of Canada in 2018. These experimental sites are spread out over three different hardiness zones, ranging from 3a to 4b, in both agricultural and forest environments. Such a broad diversity of environments has allowed for the study of environmental effects on hazelnut production parameters. In an effort to develop a phytosanitary strategy with a low environmental impact, an approach emphasizing ecosystem services has been studied in these nut groves. This approach not only seeks to avoid the use of chemicals in pest control, but also to reduce growers' workload by promoting natural biocontrol at production sites. Aware that the vegetation in orchards can attract and influence the activity of various diseases and pests as well as their predators, the research team focused its attention on identifying the plant and insect species already present at the sites. A plant and insect inventory was conducted between the rows and at the edges of 17 experimental nut groves, and insect populations were counted and divided into groups based on agroecosystem functions. The results reveal the effects of plant community composition on insect populations, making it possible to propose strategic planting that will promote the establishment of helpers in the fight against pests.	Primeau Bureau, Félix Patoine-Rivest, Raphaëlle Charbonneau, Camille Perron, Béatrice Tardif, Maxim
<b>Plant population genomics in Canadian boreal mining areas</b> Ricinodendron heudelotii (Euphorbiaceae) is an essential tree-bearing aromatic Non-Timber Forest product in West and Central Africa. The species is listed among the top five key priority species by World Agroforestry (CIFOR-ICRAF) in their tree domestication program. Seeds are the most valuable resource producing edible oil used in traditional dishes. Bioactive compounds in the seeds revealed potentialities to treat dysentery, stomachache, and fertility problems. Despite these various potentialities helping to improve the life of local small holders' farmers, the species is still significantly neglected. Data on diversity, farmers' preferences, and management strategies are missing. The aim of our study was to assess the diversity in morphotypes, farmers' attitudes, and management practices of R. heudelotii populations. A total of 117 trees were sampled, and 61 farmers were interviewed in Cameroon's Central and South regions. Preliminary results show that seeds morphotypes diversity is medium within populations. The species mainly occurs in forests (49.18%), followed by cultivation in the home garden (27.86%), justifying the fact that most of the R. heudelotii populations are wild (90%). After the floristic inventories, the main cash crops are Banana (2%), Cocoa (76%), and oil palm tree (22%), while the main associated tree species are Dacryodes edulis, Elaeis Guinensis, and Irvingia gabonensis. The kernels are predominantly used in human nutrition (76%), while the bark serves for medicinal purposes (24%). Some of the challenges farmers faced were the need for cracking machines to crack the hard shell of the nuts and the lack of processing techniques of the nuts into oil. Both measures would help to improve the livelihood strategies in rural areas. Appropriate long-term availability strategies need to be implemented to manage this helpful tree better.	Goncalves Dos Santos, Karen Cristine Porth, Ilga Villarreal Aguilar, Juan Carlos Khasa, Damase



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<p><b>Up-scaling agroforestry for biodiversity conservation around protected areas: Case study of the Santchou Wildlife Sanctuary in Cameroon</b></p> <p>Protecting areas have been the source of recurrent conflicts because of the conflicting goals of conservation and livelihood improvement. The role played by agroforestry towards biodiversity conservation has been documented by several studies around the world. However, few studies have examined the contribution of agroforestry towards biodiversity conservation in protected areas across sub-Saharan Africa in general and Cameroon in particular. This study was therefore carried out within the framework of understanding how agroforestry contributes towards biodiversity conservation, taking as case study, the Santchou Wildlife Sanctuary in Cameroon. Data for the study was collected through household surveys, key informant interviews and focus group discussions. Using Microsoft Excel 2016 and SPSS 17.0, descriptive and inferential statistics were computed. Results indicate that the main agroforestry practices of the local population living around the Santchou Wildlife Sanctuary are cocoa-based agroforestry (10%), coffee-based agroforestry (10%), mixed cocoa and coffee agroforestry (30%), and mixed cocoa, coffee, banana and oil palm agroforestry (50%). These agroforestry practices are characterized by a diversity of tree species including fruit trees (50%), bio-fertilizing trees (5%), trees for fuelwood and construction (35%), medicinal tree species (5%) and flowing trees for apiculture (5%). The local population living around the Wildlife Sanctuary report the procurement of different ecosystem services with the most common being food, fuelwood, fodder, medicinal plants, honey as well as income from the sale of products gotten from the different agroforestry systems. An inverse causal relationship was found to exist between the practice of agroforestry and encroachment into the wildlife sanctuary, indicating that the practice of agroforestry plays a major role towards reducing pressure on the biodiversity of the Wildlife Sanctuary. Based on these findings, we recommend the up-scaling of agroforestry around the Wildlife Sanctuary in order to further reduce pressure on its already depleting resources.</p>	<p>Forje, Gadinga Walter Awazi, Nyong Princely Kimengsi, Jude Ndifon</p>
<p><b>Agroforestry systems help to harbour species diversity in intensively managed agriculture landscape</b></p> <p>Worldwide biodiversity decrease relates to human population expansion and resulting landscape transformations. Many species typical for former heterogeneous landscapes with low-intensive management have completely disappeared or sharply declined in large areas of current intensive agricultural landscapes. This is related mostly to habitat destruction and management changes. To explore whether agroforestry systems could harbour such species, we surveyed birds and vascular plants on three and four localities, respectively. Birds communities helped to reveal patterns among habitats (conventional agriculture, agroforestry, younger woods, older woods), while vegetation reflected relationships inside agroforestry systems. Bird species composition in conventional agriculture completely differed from other habitats, whose species compositions overlapped (near-natural habitats and agroforestry). This pattern was revealed also in each of the five surveys during the year. The <math>\alpha</math>-diversity of agroforestry and older wood habitats was markedly higher than that found in arable land and younger woods. The main gradient in vegetation species composition followed types of cultivated crops. Nevertheless, the vegetation of field edges completely differed from field vegetation, where the crop did not directly follow agroforestry tree belts due to imperfect sieve. Younger agroforestry belts showed similar species composition of the understorey grasslands compared to open grasslands, while older agroforestry belts overlapped only partly. The</p>	<p>Vymazalová, Marie Houska, Jakub Stehno, Jiri Kotrba, Radim Lojka, Bohdan Jan, Weger</p>

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highest plant $\alpha$ -diversity was recorded in field edges, where the crop did not directly follow the tree belts. However, this habitat was also the richest in alien species. Although wider agroforestry tree belts in Šardice represent isolated islands surrounded by vast arable lands, we found there two endangered species typical for regional remnants of species-rich dry grasslands. For both birds and vascular plants, we conclude that productive agroforestry can partly substitute near-natural habitats in intensively managed agricultural landscapes that lack such habitats. The biodiversity increase depends on the age of agroforestry systems and on their spatial isolation.	
<b>Soil bacterial communities are affected by plant age and not by site of growing in chestnut plantations in the NW of the Iberian Peninsula</b> Soil microbial communities are involved in key soil processes of forest ecosystems that include decomposition of organic matter, greenhouse gases fluxes, cycling of nutrients or formation of soil structure. The composition and diversity of these communities depend on a large number of factors such as soil humidity, pH, nutrient levels, C content, or the type of vegetation cover. Plants can modify the soil bacterial communities either through a direct exchange of microorganisms (plant-soil exchange or exchange through plant litter) or indirectly through plant-induced changes in soil properties. The objective of this work was to study the importance of these interactions: and specifically, to understand in the age of trees in forest plantations can be a factor influencing soil bacterial communities. Despite the high forest area of the Iberian Peninsula, the bacterial communities of these soils are still poorly studied and characterized. This work is carried out in the interior of the region of Galicia (NW of Spain) where the main masses of chestnut trees are found. Soil samples were taken in plantations of two different ages: young plantations (10-15 years) and centennial plantations. The bacterial communities present in the organic horizon were characterized by massive sequencing of the 16S rDNA ribosomal gene. In general, the phylum Proteobacteria (indicator of mature ecosystems) dominated the community and tended to be higher in the centennial plantations. Other phyla such as Firmicutes and Chloroflexi had higher abundances in the young plantations. Analysis of community similarity clearly showed that the age of the plantation (and not the site of growing) was the main factor affecting the composition and structure of the bacterial community.	Mosquera-Losada, Rosa Ferreiro-Dominguez, Nuria Álvarez-López, Vanessa
<b>Circularity and biofertilizers in Agroforestry systems: impact on soil bacteria</b> Agroforestry systems (AFSs) are considered sustainable forms of land management, but their impact on soil microbial biodiversity remains poorly understood. Soil microbes, particularly bacteria, are ubiquitous in forest ecosystems, where they play a critical role in ecosystem functions, such as the biogeochemical cycle and nutrient transformation for plant growth. Thus, a deeper understanding of how bacterial communities respond to AFSs, especially to different management regimes and edaphic gradients, is necessary for evaluating such ecosystem processes. Moreover, bacterial communities are known to quickly and strongly respond to changes in the environment and therefore are useful as bioindicators. In this study, we describe the soil bacterial community in a silvopastoral system which was fertilised 16 years ago with two different doses of sewage sludge alone or in combination with CaCO <sub>3</sub> (during for consecutive years). The objectives were to describe (i) the community dominating the silvopastoral system and (ii) the residual effects of organic fertilisation on those communities. The bacterial community was dominated by Proteobacteria and Actinobacteria. In general, few differences at the phylum level were found among treatments and	Alvarez-Lopez, Vanessa Lado, Marcos Lamas-Freire, Alexandre Vazquez, Beatriz Mosquera-Losada, Rosa

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these were only found in the low frequency phyla. At the family level, the community was dominated by Acidobacteriaceae, Sinobacteraceae and Bradyrhizobiaceae and some statistical differences were found between treatments (for example, Bradyrhizobiaceae presented a significant lower abundance in the sewage sludge treated soils, independently on the presence of CaCO <sub>3</sub> ). When carrying out similarity analysis, the soil treatments were clearly grouped according to the presence of sewage sludge. Moreover, treatments including only organic matter application or organic matter together with CaCO <sub>3</sub> were grouped separately. In conclusion, we found that the changes on soil bacterial communities by organic amendment addition to soil lasted for 16 years. Moreover, these changes on microbial communities were also dependent on the presence or not of CaCO <sub>3</sub> .	
<b>Pollination biology of large cardamom (<i>Amomum subulatum</i> Roxb.) with special emphasis on honeybee (<i>Apis spp.</i>) and bumble bee (<i>Bombus spp.</i>) pollinators</b> The Hindukush Himalayan region encompasses a large area covering many countries in the North, South, and Central parts of Asia. People living in these mountains face huge complexities arising from several factors including terrain characteristics, micro-climates, environmental degradation, access to basic services, etc. These complexities vary as one moves geographically from one region to the other. The State of Sikkim in the North-Eastern part of India also observes similar challenges. Exposure to extreme events is location specific and communities settled in high, mid, and low altitudinal regions are differentially affected. Climate change impacts are disproportionate and influence lives and livelihoods variedly. One crucial determinant of these disproportionate impacts is gender – existing social norms determine roles and responsibilities, entitlements, and capabilities, thereby influencing the individual perceptions of shocks and susceptibility which vary across gender groups. The paper seeks to draw insights from the various field studies conducted in these locations to understand the gender vulnerabilities that manifest through a combination of complex and interlinked factors. It seeks to understand the existing social practices typically associated with these gender groups and how changes in the climate are and potentially influence vulnerability. The study makes use of qualitative research methods to understand gender roles, responsibilities. The study tries to bridge a crucial gap in research – of providing empirical evidence on gender mediated vulnerability in an under-researched climatic hotspot – the Hindu Kush Himalayan region. The study reiterates the role of place-based vulnerability in influencing lives and livelihoods and emphasizes the lack of access to human, financial, and natural capital as predominantly driving gendered vulnerabilities.	Sharma, Ghanashyam Durga P, Sharma
<b>Role of Community Forest on Conservation of Biodiversity, Carbon Regulations and Climate Resilience: A Case Study from Jaffna District, Sri Lanka</b> Depletion of forest cover, globally, is in the stage of severe threatened. As the mitigation in the areas where natural forest cover is lacking have been considerably subjected to manmade ecosystems such as community forest and plantation forest. However, value of the community forestry is unknown and there are limited studies available in Sri Lanka. Therefore, this study was carried out in a community forest at 'Solai Amman Temple' in Thenmaradchy Division of Jaffna district, Sri Lanka. Since the total forest area is 1.16 ha, full enumeration was done in the forest reserve with a division of square plot at the dimension of 20 m × 20 m. For the assessment on floristic diversity, Shannon-Weiner Index (SWI), Species Richness and Evenness were used. In addition, Importance Value Index (IVI) was calculated for the species dominance. Pan tropical allometric equations were used	Sivananthawerl, Thavananthan Thirukumaran, Umakanthan

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<p>for tree carbon stock estimation. Results of the study showed that a total of 40 species including trees, saplings, seedlings and 4 lianas were recorded from 29 families. Population density of trees, saplings and seedlings were 495, 2,307 and 5,160 stems/ha respectively and this shows the forest was in good regeneration capacity. SWI of trees, saplings and seedlings was 2.19, 1.91 and 1.36, respectively and this result showed that tree diversity was higher than saplings and seedlings. Based on the IVI, dominant species was <i>Mimusops elengi</i> L. (70) followed by <i>Sadavakkai</i> (51) and <i>Garcinia spicata</i> (47) and it was noticed that these species were frequency distributed in the study area. Mean value of the tree carbon was 218.8 Mg C/ha and it was contributed substantially by the dominant species in the forest reserve. Species area curve was clearly represented that species richness had a significant (<math>p &lt; 0.001</math>) strong correlation (0.98) over area. There was a significant (<math>p &lt; 0.001</math>) strong positive correlation between carbon stock and tree diameter (0.84) or basal area (0.95). Small number of trees with largest diameter (&gt;60 cm) were contributed to highest carbon content in the forest reserve. In addition, this forest is serving as a flood prone area and saving the village from flood hazard during the heavy rainy seasons.</p>	
<p><b>Legacy effects of agroforestry past and present</b>  Understanding the legacy effects of past land-use transitions can help in predicting how to manage future transitions to agroforestry. The New England area of the United States has experienced land-use change on an enormous scale; beginning from its long history of Native American agroforestry practices including sugar maple and ash, to the large-scale deforestation that followed its time as the breadbasket of the US in the 1700s, which was left unable to compete with Midwest fields and transitioned to increasingly less intensive agriculture systems including the Merino sheep boom of the late 1800s, followed by dairy production, and now reversion into mostly residential, privately-owned wood lots. Here we present data on a 6ha transitional agroforestry system in Hanover, NH where every stem less than 10 cm in dbh has been tagged, its diameter measured, georeferenced, and identified to species. We find evidence that the presence of historic tree fence rows and maple sugar production impacted the trajectory of forest succession into mixed maple and hemlock dominated stands. Results suggest that past land use management, including agroforestry, can have long-term impacts on the future trajectories of forest communities with implications for biodiversity, conservation, and management.</p>	Ong, Theresa
<p><b>The Central African farmers protect their fallow trees to prevent the savannisation of their landscape</b>  Background: In the traditional slash-and-burn system, widely used in southern CAR, the forest is felled and then burnt, and maize, then cassava and banana crops are planted in the ashes. Three or four years later, the plot is abandoned and left fallow, without any management until the next clearing. A study of the evolution of the landscape south of Bangui, the country's capital, shows that this practice leads to the retreat of the forest, replaced initially by a patchwork of degraded forest and <i>Chromolaena odorata</i> scrub, then by <i>Imperata cylindrica</i> savannahs where agriculture becomes almost impossible. To avoid this degradation of ecosystems, leading to soil impoverishment, loss of biodiversity, carbon emissions and the flight of populations, the PDRSO project introduced farmers in several villages to a technique of Assisted Natural Regeneration (ANR), which makes it possible to protect young trees during the cropping cycle so that the fallow land is made up of a stand of trees and not of invasive bushes and grasses. Method: A negotiation phase between the farmers and the researchers made it possible to</p>	Kpolita, Arnot Dubiez, Emilien Yongo, Olga Peltier, Regis

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<p>choose the species of interest and the technique to conserve them. Monitoring of 24 plots with ANR and 20 control plots without ANR, made it possible to assess the growth of woody plants. Surveys of farmers who had participated in the operation and those who had not, allowed us to assess their perception of the method and their willingness to continue it over time. Results: Two years after the selection of the young trees, they already exceed the size of the main invasive species and slow down their establishment. In addition, the farmers see the importance of preventing their village territory from being transformed into barren savannah. Difficulties reported include insecurity of land tenure, lack of support from the administration, the brevity of projects, the difficulty of fighting fires due to lack of collective organization, all in an environment of civil war. Discussion and Conclusion: The ANR technique appears to be a simple, low-cost technique that can stop the degradation of landscapes on the border between forest and savannah. However, large-scale application requires a secure environment that the population hopes will improve.</p>	
<p><b>Diversity of Antagonistic Fungi and Entomopathogen Fungi in Pine Leaf Litter and Rhizosphere of Monoculture Pine and Intercropping Pine - Coffee in UB Forest, Malang</b></p> <p>The UB Forest area is one of agroforestry system in Malang. It has the potential for the existence of antagonistic fungi and entomopathogen fungi with the diversity of vegetation in the area. This study was conducted to determine the diversity of antagonistic fungi and entomopathogen fungi in the rhizosphere and pine leaf litter on pine monoculture and intercropping pine - coffee. The research method started from plot determination, sampling, fungal identification, antagonist test and pathogenicity test. The results of isolation of fungi from pine leaf litter on monoculture pine and intercropping pine-coffee fields obtained 17 genus of fungi. In monoculture pine found 9 genus of fungi and 4 unidentified. In pine-coffee intercropping land found 13 genus of fungi. Base on potential and ability test of exploration result of fungi, founded The isolate Acremonium sp. 3 and Penicillium sp. 2 has the highest inhibition and isolate Paecilomyces sp. 1 and isolates Paecilomyces sp. 2 has the best level of pathogenicity and mortality. The factors of air temperature and humidity did not affect the diversity of fungi. The diversity of entomopathogenic and antagonistic fungi was higher in the pine-coffee intercropping land use. The litter plots had higher fungal diversity than the rhizosphere.</p>	<p>Febriansyah, Muhammad Rachmawati, Rina Abadi, Abdul Latief</p>
<p><b>Mangrove conservation through sustainable agroforestry practices along the coast: The example of the Mangrove Ecosystem in Cameroon</b></p> <p>Mangroves are an important and biodiversity rich plant ecosystem found across coastal areas in the tropics. They play a major role in climate change mitigation and provide a plethora of other ecosystem services including habitat for fish and aquatic animals. However, in recent years, mangrove deforestation and degradation has become the norm across the tropics in general and Cameroon in particular owing largely to urban expansion and increasing energy needs especially for mangrove fuelwood. This study was therefore conducted to show the vital role that agroforestry can play towards stemming the tide of mangrove deforestation and degradation across the coast of Cameroon. Data was collected across the entire coast of Cameroon through household surveys, key informant interviews and focus group discussions. Analysis was done using Excel and SPSS. Findings showed that the main mangrove species largely exploited for fuelwood and other uses across the coast of Cameroon are Rhizophora sp (80%) and Avicennia sp (20%) owing to their multipurpose uses. Dominant agroforestry practices along</p>	<p>Forkam, David Chik Ajonina, Gordon Awazi, Nyong Princely</p>

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the coastal areas of Cameroon are cocoa-based agroforestry, oil palm-based agroforestry, rubber-based agroforestry, banana-based agroforestry, and mixed cocoa and oil palm agroforestry. These different agroforestry systems are characterized by different tree species including fruit trees, bio-fertilizing tree, trees for fuelwood and construction, medicinal trees, as well as flowering trees for apiculture. These agroforestry systems and the different tree species found therein provide locals with ecosystem services like fuelwood, fodder, food, soil fertility improvement, honey as well as income from the sale of products from the different systems, which helps to reduce pressure on the mangrove ecosystem. An inverse causal relationship was found to exist between the practice of agroforestry and exploitation of mangrove for fuelwood and other uses, implying that the practice of agroforestry limits pressure on the mangrove ecosystem in the coastal region of Cameroon.	
<b>Conserving biodiversity for ecotourism enhancement in and around protected areas: assessing the role of agroforestry</b> Agroforestry as an agroecological pathway to biodiversity conservation has been examined by different studies around world. However, little or no research has been done to assess how agroforestry can be used to conserve biodiversity for ecotourism enhancement in and around protected areas. This study was therefore undertaken to fill this knowledge gap. Data was collected from three protected areas in Cameroon: Mount Cameroon National Park, Bakossi National Park and Campo Ma'an National Park, all found in the southern part of Cameroon. Findings showed that a plethora of agroforestry systems were practiced by the local population living in and around these protected areas with the most common being agrosilvopastoral, silvopastoral and agrosilvicultural. These agroforestry systems provided the local population with products and services such as food, wood, fodder, meat, traditional medicines, honey, improved soils, pollination, building materials as well as income from the sale of agroforestry products. With these diverse products and services provided by different agroforestry systems, agroforestry practitioners in the different communities in and around the different protected areas scarcely encroached into the protected areas for hunting/poaching, as well as harvesting of timber and non-timber forest products. Agroforestry practitioners in and around these protected areas equally looked at ecotourism favourably and were more willing to conserve biodiversity in and around the different parks for ecotourism purposes. This was in sharp contrast to non-agroforestry practitioners who saw protected areas as their legitimate property and a gift from their forebears, thus less willing to conserve it for ecotourism's sake. Non-agroforestry practitioners were those mostly involved in hunting/poaching as well as harvesting of timber and non-timber forest products within the different national parks. We therefore recommend that local populations around protected areas be encouraged to practice agroforestry in order to better conserve biodiversity for ecotourism enhancement.	Awazi, Nyong Princely Forje, Gadinga Walter Avana-Tientcheu, Marie-Louise Temgoua, Lucie Felicite Tchamba, Martin Ngankam
<b>Harvesting Sap and Producing Syrup from Trees Other than Maples, Birches, and Walnuts</b> The booming maple ( <i>Acer</i> spp.) syrup industry in northeastern North America it is based almost entirely on a single species, sugar maple ( <i>Acer saccharum</i> ). Smaller, but still important, birch ( <i>Betula</i> spp.) and walnut ( <i>Juglans</i> spp.) syrup industries exists in some parts of North America as well. With growing threats from climate change, pests, and pathogens, there is uncertainty about the ecological and economic sustainability of the maple syrup industry. Diversifying sugarbushes to include other tree species with a high potential for syrup production offers an	Moore, David Gutierrez Lopez, Jose Vadeboncoeur, Matthew Asbjornsen, Heidi



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<p>opportunity to enhance the long-term sustainability of the syrup industry in the region. We are conducting a three-part study to determine which novel tree species can be used for syrup production and their respective production methods. First, we use sap flow sensors to collect continuous sap-flow data in novel species throughout winter dormancy, and we collect concurrent environmental data to determine the environmental drivers of these sap flows. Second, we harvest sap and produce syrup from these species to determine their feasibility for syrup production. Third, we use chromatography and mass spectrometry to determine the chemical compositions of these saps and syrups; chemical composition informs how sap should be processed into syrup and can be used to identify the presence of healthy, medicinal, or poisonous compounds. Our preliminary results suggest that beeches, sycamores, and hophornbeams are viable syrup-producing species, whereas ashes, hickories, basswoods, and poplars might not be. All these species exhibit winter-dormant-season sap flows, and most, but not all, of these sap flows are driven by freeze-thaw cycles. Since many of these syrups have unique, delicious tastes, they are expected to be popular with consumers, and they will provide producers with unique, marketable products for a small amount of additional work since producers already have much of the necessary infrastructure.</p>	
<p><b>Morphological diversity of <i>Vitellaria paradoxa</i> (C.F.Gaertn) along agroecological gradients in Cameroon</b></p> <p><i>Vitellaria paradoxa</i> (Sapotaceae), commonly known as 'shea', is one of the most important trees for improving local livelihood in West and Central Africa. The most used product is kernels from which oil commonly referred to as "Shea butter," used as a raw material for many cosmetic and pharmaceutical industries, is extracted. While providing potential economic benefits for the local community, the species is under threat, and the International Union for Nature Conservation has red-listed in the category of vulnerable species. Therefore, conservation measures must be put in place. One of the starting points is the assessment of genetic diversity, since available information is still limited for the species. The general objective of this study was to evaluate the morphological differences in the characteristics of the shea tree and fruit along the agroecological gradient in Cameroon (western highlands, Guinean high savannah, Soudano-Sahelian). A total of 167 trees were randomly selected and 2,211 kernels were collected at three agroecological sites. The numbers of trees sampled in the three populations were 60, 65, and 56, respectively. The measured fruit traits were kernel length, weight, width, DBH, crown diameter, height. The data were analyzed using descriptive statistics and inferential analysis (ANOVA). The result revealed statistically significant differences, found between the three agroecological areas in height (<math>P &lt; 0.001</math>), DBH (<math>P &lt; 0.001</math>) and crown diameter (<math>P = 0.001</math>). Strong correlation between kernel parameters (length, width) and kernel weight at <math>P &lt; 0.001</math>. The five best trees with superior features identified were VP/NG/126, VP/NG/155, VP/NG/132, VP/NG/31, VP/NG/129, depending on the kernel weight, as it is one of the main factors for oil production industries. The findings will improve (1) the better selection of <i>V. paradoxa</i>, leading to the development of new cultivars with the desired traits to improve its domestication program and (2) conservation by producing a map of morphological diversity.</p>	<p>Patrick Bustrel, Choungo Nguenkeng Prasad, Hendre Alice, Muchugi Zacharie, Tchoundjeu Alain, Tsobeng Tariku Olana, Jawo Marie, Kalousova Bohdan, Lojka</p>



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<p><b>Morphological diversity, farmers' perceptions, and the silvicultural management of <i>Ricinodendron heudelotii</i> (Baill.) Heckel populations from Cameroon</b></p> <p><i>Ricinodendron heudelotii</i> (Euphorbiaceae) is an essential tree-bearing aromatic Non-Timber Forest product in West and Central Africa. The species is listed among the top five key priority species by World Agroforestry (CIFOR-ICRAF) in their tree domestication program. Seeds are the most valuable resource producing edible oil used in traditional dishes. Bioactive compounds in the seeds revealed potentialities to treat dysentery, stomachache, and fertility problems. Despite these various potentialities helping to improve the life of local small holders' farmers, the species is still significantly neglected. Data on diversity, farmers' preferences, and management strategies are missing. The aim of our study was to assess the diversity in morphotypes, farmers' attitudes, and management practices of <i>R. heudelotii</i> populations. A total of 117 trees were sampled, and 61 farmers were interviewed in Cameroon's Central and South regions. Preliminary results show that seeds morphotypes diversity is medium within populations. The species mainly occurs in forests (49.18%), followed by cultivation in the home garden (27.86%), justifying the fact that most of the <i>R. heudelotii</i> populations are wild (90%). After the floristic inventories, the main cash crops are Banana (2%), Cocoa (76%), and oil palm tree (22%), while the main associated tree species are <i>Dacryodes edulis</i>, <i>Elaeis Guinensis</i>, and <i>Irvingia gabonensis</i>. The kernels are predominantly used in human nutrition (76%), while the bark serves for medicinal purposes (24%). Some of the challenges farmers faced were the need for cracking machines to crack the hard shell of the nuts and the lack of processing techniques of the nuts into oil. Both measures would help to improve the livelihood strategies in rural areas. Appropriate long-term availability strategies need to be implemented to manage this helpful tree better.</p>	<p>Patrick Bustrel, Choungo Nguekeng Mustapha, Yakubu Madaki Anna, Ma'ourová Armelle Verdiane, Tchanou Tchapda Dennis, Kyereh Marie, Kalousova Alain, Tsobeng Bohdan, Lojka</p>
<h3>D. Transitioning to a Viable Climate</h3>	
<p><b>Can the REDD+ program support the development of agroforestry for the resilience of Cameroonian highland populations to climate change?</b></p> <p>The agricultural activity of smallholders is confronted with multiple environmental challenges that make them vulnerable to climate change and severely impact product quality and yield. Agroforestry is promoted in the climate strategy of all tropical countries as a climate-smart agricultural practice that can contribute to the process of reducing emissions from forest degradation and deforestation while preserving existing sinks and increasing their potential sequestration (REDD+). To better understand the potential of REDD+ projects in promoting agroforestry in Cameroon, we conducted semi-structured interviews with 28 actors from the REDD+ technical secretary and local organizations with the objective of understanding the involvement of various organizations in agroforestry projects and the benefits for the peasant communities involved. The results show that five REDD+ pilot projects have been submitted for the five agro-ecological zones of Cameroon of which only one has been implemented to date. The analysis of project documents shows that they integrate agroforestry as an essential technique for the regeneration of degraded areas (3000 ha of forest reforested) and the improvement of arable soils (45,000 plants planted). The strategies proposed by the project leaders to facilitate the adoption of agroforestry in the communities include the use of free, informal, and prior consent, sensitization, seed distribution, training of farmers on the nurseries</p>	<p>Chamdjou Tchamdjou, Junie Brodelle Bissonnette, Jean François Gélinas, Nancy Khasa, Damase Sonwa, Denis</p>

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establishment and transplanting of seedlings. Constraints identified for the promotion of agroforestry include unfamiliarity with the technological approach and lack of funding. These realizations by REDD+ technical service have led to a readjustment of benefit-sharing mechanisms and conflict management and the establishment of an environmental and social management framework. REDD+ project activities are currently at a standstill due to lack of funding and require financial from donors. This study demonstrates how agroforestry can be integrated into the actions of Cameroon's national REDD+ program and highlights the limitations to disseminating these actions.	
<b>Agroforestry as a means to strengthen adaptation to climate change in Senegal:</b> An analysis based on 120 development and research projects Located mostly in an arid climatic zone, Senegal is facing significant challenges to guarantee the food security of its population amidst marked demographic growth and the continuing degradation of its natural resources. Climate change constitutes a major threat to the attainment of such challenges and it is urgent to strengthen the adaptation level of the country's agricultural sector and to minimize the negative effects inflicted upon rural communities. Thus, a project was carried out in order to identify the various contributions that agroforestry could bring in an optic of adaptation to climate change across the different agroecological regions of the country. Through a comprehensive documentary review conducted across Senegal and interviews with various national experts, information relative to more than 120 agroforestry projects led in the country over the last decades has been gathered. The analysis of those projects –which included both development and research initiatives–, highlighted key benefits that various agroforestry systems could play to help local communities deal with impacts such as temperature rises and increased rainfall variability. The restoration of parklands appears for instance as a good strategy to lower field temperatures and reduce the productivity losses associated with water and heat stress. Other new techniques such as native shrubs intercropping also seem really promising and could increase crop resistance to drought through the protection offered by the mulch it generates and mechanisms of hydraulic redistribution. Beyond their contributions to soil health, water balance, microclimate, pest control and yield, agroforestry initiatives may also support the empowerment of farmers. The combination of traditional and innovative agroforestry practices has the potential to improve the resilience of Senegalese rural communities in the face of climate change while alleviating food insecurity.	Richard, Catherine Bonneville, Jean Marone, Diatta Bérubé-Girouard, Victor Olivier, Alain
<b>Gender-driven dynamics of agroforestry practice and climate change adaptation in rural agrarian systems in the Western Highlands of Cameroon</b> Rural agrarian systems are bearing the brunt of the adverse effects of climate change (CC) owing to their high level of vulnerability to extreme climate events. Agro-ecological farming practices like agroforestry are being increasingly taken up by peasant farmers (men and women) in an attempt to counter the effects of CC. In Cameroon limited research has been carried out examining how gender influences agroforestry practices (AFPs) and CC adaptation as well as rural agrarian change. This study was therefore undertaken to fill the knowledge gap. Data was collected through 770 household surveys, 50 key informant interviews and 10 focus group discussions. Analysis was done through descriptive and inferential statistics as well as content and theme-based analysis using SPSS and Excel. Findings revealed that, faced with CC, women mostly adopt AFPs like home garden, home garden with animals, and improved fallows while men mainly adopt AFPs like trees on croplands, and coffee-based agroforestry. Women's practice of	Awazi, Nyong Princely Avana-Tientcheu, Marie-Louise Temgoua, Lucie Felicite Tchamba, Martin Ngankam

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agroforestry faced with CC is mainly influenced by access to land, markets, information; farm size, educational level and age while for men it is mainly influenced by access to extension services, income, and credit; age and farm size. Women's adoption of different AFPs like home garden, home garden with animals and improved fallows is largely influenced by access to land, age, educational level, and farm size while for men, adoption of AFPs like trees on croplands and coffee-based agroforestry is mainly influenced by age, income, access to credit and farm size. These findings demonstrate that in the midst of CC, men are more involved in tree intensive AFPs while women are more involved in food-based AFPs. Thus, gender-driven AFPs in the midst of CC influence adaptation as well as rural agrarian change in rural Cameroon.	
<b>Implementing agroforestry systems in cocoa production as climate change adaptation methods - Case study from Ivory Coast</b> Cocoa production in Ivory Coast plays an important role in the country's economy and farmer's livelihood. In the last decade, aging of the plantations, which have been traditionally cultivated under direct sun, attacks from pests and disease, and climate change have triggered a series of challenges in the Ivorian cocoa production. In 2019, SOCODEVI teamed with multiple partners including Ouranos, a Canadian consortium on regional climatology and adaptation to climate change, and West-African and Ivorian organizations: WASCAL (West African Science Service Center on Climate Change and Adapted Land Use), more specifically their Ivorian pole CEA-CCBAD (Centre d'Excellence Africain sur le Changement Climatique, la Biodiversité et l'Agriculture Durable) of the University Félix Houphouët-Boigny, ANADER, the national agency for agricultural extension services and CNRA, the national center for agronomic research. Together they initiated an applied research project funded by the International Development Research Center (IDRC) entitled AdaptCoop whose main objective is to sustainably increase the resilience of cocoa cooperatives and member families when dealing with the impacts of climate change in Ivory Coast. Most promising agroecological adaptation practices adopted by women and men cocoa farmers were analyzed based on multiple criteria, including the implications of climate scenarios developed within the project. The presentation will focus on the results of this multicriteria analysis and the implementation results of promising agroecological adaptation practices at the farmers' level, many of which are linked with agroforestry systems. Furthermore, the adaptation strategies of cooperatives to respond to their members needs, with a gender-sensitive approach, and to ensure that their own activities, products, and services integrate changing climate realities and the needs expressed for agroforestry systems will be highlighted. As the latest results will be available shortly, a fresh update will be presented to your audience on adaptation to climate change using agroforestry systems in Ivory Coast.	Brunelle, Renée M'bo, Kacou Alban Antoine Okou, Alla Kouadio Tchéma, Rachel Levasseur, Virginie
<b>Supporting farmers to understand and to seize opportunities from the carbon markets and offset credits in the Province of Quebec (Canada)</b> Canada, like many countries, has committed to reducing its GHG emissions by 40-45% by 2030, to limit global warming. To achieve this, all sectors of activity must contribute, including agriculture. However, Quebec's agricultural community lacks knowledge about the possibilities of reducing and absorbing GHGs in farm operations. In this context, the Ministry of Agriculture, Fisheries and Food of the Province of Quebec has mandated CERFO to develop popularized material intended to inform farmers on GHG reduction and absorption activities that could be implemented, as well as on the opportunities in terms of offset credits. This	Boulfroy, Emmanuelle Vézina, André

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project relied heavily on extensive literature research and consultation with experts in the field of carbon offsets. The information gathered was then synthesized and popularized in several technical sheets, targeting agricultural extension officers, to facilitate knowledge sharing with agricultural producers. Some key theoretical notions are presented, for a good understanding of the possible options available to agricultural producers: the functioning of the regulated and voluntary carbon markets in Quebec, their stakeholders, the specific conditions where these markets apply, as well as the regulations allowing the certification of GHG reductions or absorptions in the agricultural sector. Tree plantation in agricultural areas, based on agroforestry schemes, is one of the promising ways to sequester GHGs, and eventually generate revenues through the sale of offset credits. The different offset programs available in the province of Quebec and applicable to the agricultural context will also be presented, as well as the steps to follow to take advantage of them.	
<b>Planting agroforestry leguminous species in association with Robusta coffee: a method to reduce the effect of climate change on coffee cultivation in Togo</b> Introduction: The coffee tree is a tropical shade plant, cultivated in areas where the dry season does not exceed three months. In Togo, in recent decades, the seasons have been marked by climate change characterized by the lengthening of the dry season, which is detrimental to the yield of the coffee tree, reducing the quantity of marketable coffee and revenue from export. Hence, it needs to search for alternative measures for reduction of the effects of CC on coffee production. Methodology: The association of agroforestry leguminous species ( <i>Albizia adianthifolia</i> , <i>Samanea saman</i> , <i>Erythrophleum guineensis</i> , <i>Albizia lebbeck</i> ) with the cultivation of coffee trees, the observation of the evolution of the shaded size of these species and the determination of the yield of coffee trees grown in association, were the methods used. The trials lasted from 1995 to 2018 at Tové's station of coffee cultivation in Togo. Results: The ground cover span of <i>Albizia adianthifolia</i> is 86m <sup>2</sup> , 217m <sup>2</sup> , 226m <sup>2</sup> and 235m <sup>2</sup> respectively at the age of 5 years, 10 years, 15 years and 20 years. That of <i>Erythrophleum guineensis</i> is 44m <sup>2</sup> , 132m <sup>2</sup> , 175m <sup>2</sup> and 216m <sup>2</sup> at the same ages while it is 126m <sup>2</sup> , 254m <sup>2</sup> , 290m <sup>2</sup> and 327m <sup>2</sup> for <i>Samanea saman</i> . The floor covering is of <i>Albizia lebbeck</i> is 139m <sup>2</sup> and 197m <sup>2</sup> at the age of 5 years and 9 years respectively. The commercial coffee yields of Robusta coffee under forest leguminous after five years are: <i>Albizia adianthifolia</i> 851kg/ha, <i>Samanea saman</i> 1024kg/ha, <i>Erythrophleum guineensis</i> 1068kg/ha and <i>Albizia lebbeck</i> 1492kg/ha, NPK at 400 kg/ha, 1336kg/ha, Control 986kg/ha. Without association with Leguminous, Robusta yields are 563kg/ha, NPK at 400 kg/ha 281kg/ha and Control 195kg/ha. Discussions: In association with agroforestry leguminous, the yields of Robusta coffee are higher than for cultivation without association. Conclusion: Agroforestry in coffee cultivation can constitute a palliative for climate change in tropical areas.	Tefe, Yawo Kafui Prince Koudjega, Tchimondjro Koudouvo, Koffi Reboud, Apolline Dahounom, Aboudou Azizou Edah, Koffi Aka, Amivi Jacqueline Djissenou, Kodjo Akpodo, Kossi Minontikpo
<b>Togolese municipal communities of Yoto District engaged in reforestation and agroforestry for the fight against global climate change</b> Introduction: The Togodo-South National Park in the Yoto District is the only flora and fauna reserve that contributes to the fight against climate change in the south of Togo. In recent years, we have witnessed a resurgence of interest in promoting reforestation to compensate for the vegetation cover destroyed despite insufficient cultivable land due to population expansion. Methodology: A participatory approach to Reforestation and Agroforestry (R&Af) born within grassroots communities in Yoto brought together development leaders on November 2 and 3, 2021 for the 1st community days of reflections on the theme:	Dahounom, Aboudou Azizou Aka, Amivi Koudouvo, Koffi Edah, Koffi Adoh, Koffi Kounousse, Kodjovi Ezounou6 Akpodo, Kossi Minontikpo Apolline, Reboud Aziafon, Ayawovi Kodjo, Djissenou

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<p>Reforestation and Agroforestry for development sustainable. A semi-structured survey was carried out to identify food crops and forest plants that can be cultivated in association, the strengths of R&amp;Af and the difficulties likely to hinder its promotion. Four university trainers and fourteen local elected officials and traditional leaders participated. Results: Ten food crops suitable for agroforestry were identified, including: corn (30.61%), peanuts (16.33%), bean (16.33%). Among the 16 forest species recorded, we note primarily <i>Mangifera indica</i> (9 citations), <i>Khaya</i> ssp (7 citations), <i>Citrus orantium</i> (6 citations) and <i>Tectona grandis</i> (5 citations). Nutrition, agricultural development, poverty reduction and carbon credit, are the benefits of R&amp;Af for the locality. Insufficient space, lack of awareness, difficulties in choosing the species to plant, bad weather, drought and transhumance, constitute obstacles to the promotion of R&amp;Af. The <i>Khaya grandifolia</i> species was selected for the R&amp;Af valuation in three communes of Yoto. Discussion: As the vegetation cover of Yoto prefecture deteriorates year after year, this R&amp;Af initiative will certainly have a positive influence on sustainable development in the area. The inherent participatory approach is unprecedented involving grassroots communities. Conclusion: The assets presented by the area will be highlighted and obstacles will be overcome to promote reforestation and Agroforestry.</p>	
<p><b>Bamboo-based agroforestry for climate change mitigation and adaptation in Cameroon: State-of-the-art and perspectives</b></p> <p>Bamboo is one of the most important but neglected non-timber forest products (NTFPs) in sub-Saharan Africa in general and Cameroon in particular. In Cameroon, a cross section of the population view bamboo as an invasive plant species with little or no economic potential. Thus, across most communities, bamboo is being destroyed at an alarming rate either through burning or wanton cutting. Some studies have been conducted in different parts of the world showing the importance of bamboo to climate change mitigation and adaptation, with very limited studies done in Cameroon. It was in this light that this study was conducted to examine how bamboo-based agroforestry systems contribute towards climate change mitigation and adaptation. Biophysical and socio-economic data was collected across the five agro-ecological zones of Cameroon. Data analysis was done using R-software, Excel and SPSS. Results showed that although bamboo-based agroforestry systems are not yet too common across Cameroon, the main bamboo species common in the few existing bamboo-based agroforestry systems are <i>Bambusa</i> sp (60%), <i>Phyllostachys</i> sp (30%), <i>Yushina alpina</i> (5%) and <i>Ochlandra travancorica</i> (5%). These bamboo species have a high carbon sequestration potential which can be attributed to the fast growing nature of bamboo, indicating that bamboo contributes enormously to climate change mitigation. Socio-economic analysis revealed that bamboo-based agroforestry systems contribute to climate change adaptation through the provision of different ecosystem services like food, fodder, soil fertility improvement, fuelwood, medicines and income obtained from the sale of bamboo products which assist the local population to adequately adapt to climate change. Although this study has shown that bamboo-based agroforestry systems contribute to climate change mitigation and adaptation, more research needs to be done to identify the different types of agroforestry systems in which bamboo thrives as well as the contributions of each bamboo species to climate change mitigation and adaptation in the different agroforestry systems.</p>	<p>Nforinkah, Neba Barnabas Chimi, Djomo Cedric Awazi, Nyong Princely Forje, Gadinga Walter Enongene, Kevin Kaam, Rene Tanougong, Armand Tchamba, Martin Ngankam</p>



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<p><b>Assessment of Desertification Status and Trend Based on SARVI and GSI in West Omdurman, Sudan</b></p> <p>The study was carried out in West Omdurman in EL Rawkeeb area (423418 km<sup>2</sup>), located about 40 Km south west the capital Khartoum. The study aimed to assess and map desertification status and trend in 1980 - 2019 using vegetation and soil indices (SARVI and GSI), based on two biophysical indicators (vegetation and soil degradation). The study used the Earth Explorer program to download the satellites images of west Omdurman locality, the program (Arc Map) was used to analyze image and made maps of study area and the Excel to made charts and other shapes for more analysis. The results showed that, very severe and severe classes of desertification grades represent 60.6% of the study area. The areas of moderate class of desertification account to 27.8% of study area, and the areas of light and non-desertification classes of desertification represents 9.8% and 1.8% of study area respectively.</p>	<p><b>Salih, Yousif Mohamed Ibrahim</b></p>
<p><b>Using a probabilistic graphical model as a tool to infer the carbon stock in coffee agroforestry systems</b></p> <p>Agroforestry systems have been identified as one of the production systems capable of helping mitigate climate change because of the carbon sequestration potential in the tree and crop components. In the case of coffee agroforestry systems (CAFS), the structure and composition of the shade component could be highly diverse, so their carbon sequestration potential. The carbon stock estimations from biomass in CAFS are commonly calculated using allometric equations and the corresponding sampling data from trees and coffee plants. The shade component (type) corresponds to the farmers' production strategy and, therefore, to the state of other components (e.g., coffee plants, intensification) in the coffee system, so changes in the shade component should be together with other changes in the system. Adapting to climate change will require adjustments in farmers' practices and strategies; for some, it may include changes in the tree component or incrementing the shade levels to cool the higher temperatures or both. This study aims to introduce a Bayesian Network (BN) model to explore the implications of changes in the farming practices on the carbon stock in CAFS. BNs are probabilistic graphical models that can use data and expert knowledge to build models and infer even under missing data. The model was built using a set of allometric equations for trees (woody and musaceas) and coffee plants in junction with data from a survey in coffee farms. The model parameters were populated using machine learning from data. The model estimates below and aboveground biomass for different types and shade levels; the type and shade levels are linked to farming intensification variables. The model can help decision-makers and practitioners explore the impacts of changes on the trees and coffee component on the carbon stock potential and the farming intensification.</p>	<p><b>Lara-Estrada, Leonel</b></p>
<p><b>Quantification of Driver of REDD+ Activities</b></p> <p>This study aims at the quantification of the area affected by the drivers of deforestation and forest degradation in Sudan during 2019. The Methodology encompassed a mix of quantitative and qualitative data collection from secondary as well as primary sources. The primary data sources included questionnaire and field forms were designed and filled for data to be directly to be collected through field visits to deforestation &amp; forest degradation sites, consultation virtual meetings with key forestry officers and key informants including community, tribal and local leaders. Statistical package for social science (SPSS) was used to analyze the data. According to the result obtained the most of the forest are medium density with ratio 39.1%, 38.6% regeneration of the forests were good. The most activates were practice in the forests is agriculture and grazing, 50%. Goat is most of animal grazing in the forest 48.3% are: goat, camels, caws and sheeps. The</p>	<p><b>Mohamed, Satti Siddig, Ahmed Khalil, Sayeda</b></p>

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<p>agriculture expansion is very important drivers represented by 51% with the total area 940,319.85 fedan. Over grazing represented by 34% with the total area 631,589.31 fedan. In the context to access recommendation. Human settlement the result was shown that they cannot found human settlement such as (compound refugee, village and house) estimated by 13, 543, 00 fedan with ratio 0.7%. Accordance to aims at the Helping the communities to enhance agriculture production, reduce shifting cultivation and process of market behavior. Promoting alternative source of livelihood for the community e.g. by employing young people as forests range technical skills, supporting cooperative loans and improving education. Fire management unit should be established to control the fire in the all-state (18) state with capacity building and training of the staff.</p>	
<p><b>Silvopasture and carbon associated with the soil aggregate fractions in Galicia (NW Spain)</b></p> <p>Soils play an important role in climate change mitigation by storing carbon and decreasing greenhouse gas emissions in the atmosphere. In the soils, carbon can be stored in macroaggregates (250-2000 <math>\mu\text{m}</math>) in the short-term and microaggregates (53-250 <math>\mu\text{m}</math>) and smaller aggregate sizes (&lt;53 <math>\mu\text{m}</math>) in the long-term. However, the carbon associated with the different soil aggregate fractions can vary over time and there is a lack of knowledge when silvopasture is established as land use. This study aimed to evaluate the silvopasture effect on the carbon storage in each soil aggregate fraction (250–2000 <math>\mu\text{m}</math>; 53–250 <math>\mu\text{m}</math> and &lt;53 <math>\mu\text{m}</math>) in silvopastoral systems established under <i>Pinus radiata</i> D. Don with different tree canopy covers in Galicia (NW Spain). In September 2020, a total of 48 plots with <i>Pinus radiata</i> D. Don and different tree canopy covers (0, 50 and 100%) were selected around Galicia. Twenty-four plots had a silvopasture land use and 24 plots had forest land use. In each plot, composite soil samples were collected at a soil depth of 25 cm. In the laboratory, soil samples were fractionated into macroaggregates (250-2000 <math>\mu\text{m}</math>), microaggregates (53-250 <math>\mu\text{m}</math>) and smaller aggregate sizes (&lt;53 <math>\mu\text{m}</math>) to estimate the carbon storage in the different soil fractions. Data were statistically analysed with ANOVA. The results showed that silvopasture increased the amount of carbon storage in the smallest soil fractions. Therefore, silvopasture could be promoted as sustainable land use for climate change mitigation due to its capacity to sequester carbon in the soil in the long-term. Acknowledgements: This study has been supported by Xunta de Galicia, Consellería de Cultura, Educación e Ordenación Universitaria (“Programa de axudas á etapa posdoutoral modalide B DOG nº 213, 08/11/2019 p.48018, exp: ED481D 2019/009”) and the Pilot Program of the University of Santiago de Compostela (USC) for the hiring of distinguished research staff - call 2021, funded under the collaboration agreement between USC and Banco Santander, for the years 2021-2024.</p>	<p>Ferreiro-Domínguez, Nuria Rigueiro-Rodríguez, Antonio Mosquera-Losada, María Rosa</p>
<p><b>Agroforestry and Climate change</b></p> <p>AF is a sustainable land use system and the most promising agricultural practice to mitigate climate change while providing climate and market resilience. The climate mitigation potential is based on the increase of the Leaf Area Index per hectare that the woody component (trees or shrubs) provides which enhance light efficient use increasing biomass production per hectare (main source of carbon stocks). Soil carbon is one of the main components of the carbon stocks in the terrestrial ecosystems, being this fact at the heart of the initiative 4 per thousand approved in the COP 21 held in Paris, as highlighted the EC proposal to plant 3 billion trees in the EU. However, and in spite of this fact, soil carbon is only mentioned in 6 out of the 191 Nationally Determined Contributions forming part of UN (NDC). Moreover, the carbon offsetting projects, the main mechanism that Member States (MS) have to recognize carbon credits associated with agricultural</p>	<p>Mosquera, Maria Jose Javier, Santiago Freijanes Francisco Javier, Rodriguez-Rigueiro</p>



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<p>lands afforestation does not include soil in their accountability. This accountability should consider (i) the soil organic carbon layer depth and (ii) the soil carbon composition to pay farmers to sequester carbon while reaching the EU farming climate neutrality goal. Climate resilience is linked to the trees and shrubs capacity to reduce (i) wind negative effects increasing water use efficiency, the extreme heat effects on cereals but also to (iii) improve animal welfare. This will be the baseline to enhance the provision of ecosystems services in both organic and conventional farming systems representing the 91.5% and 8.5% of the European farming systems.. The livestock sector directly represents the 70% of the GHG emissions. Livestock farm's feed self-sufficiency is relevant to reach the European farm sustainability and carbon neutrality as it increases biodiversity (linked to a mosaic landscape integrating crop rotation (grassland and croplands).</p>	
<p><b>Conserving springs as climate change adaptation action in the eastern Himalaya</b>          Springs are the most important source of water for millions of people in the Himalayas. Both rural and urban communities depend on springs for meeting their drinking, domestic, and agricultural water needs. There is now increasing evidence of springs drying up or their discharge reducing, as a result of which communities are facing water stress. The science of springs and hydrogeology are usually not well understood; aspects like linking recharge areas, the movement of groundwater, and the difference between 'source' and 'resource' of springshed systems need to be demystified to local communities, administrators, and landowners. Springs are also part of complex social and informal governance systems, which are often inadequate both in terms of governance and management of the sources. This study identifies and maps spring systems, water budgeting, groundwater flows, and governance issues around the pilot areas of the Chibo–Pashyor watershed of Kalimpong. A total of 55 springs were mapped in the study site and 12 critical springs were selected for monitoring and detailed study, based on vulnerability criteria developed for this research. An analysis of water access, discharge, and budgeting, based on the "National Rural Drinking Water Programme Guidelines 2013", was also conducted. Furthermore, to understand spring sources and resources, as well as recharge areas, hydrogeological and lithological studies, were conducted. The findings show that mountain aquifers are connected by fractures, having multiple recharge and discharge points along the elevation gradient. These rain-fed aquifers are sensitive to rainfall patterns as they do not have the capacity for multi-year storage. Landscape-level recharge projects on hilltop forests benefitted springs in the lower and middle part the most, and an intensive socio-economic assessment further reinforced the theory of connected aquifers. Based on this understanding, scaling up spring revival, by graduating from 'springcentric' to 'aquifer-centric' approaches is proposed.</p>	<p>Sharma, Ghanashyam</p>
<p><b>Microclimate effect of trees: do they really cool down air and crop temperature?</b>          Trees are generally credited with a high potential for climate change adaptation of agriculture: thanks to the shade they provide, trees offer protection for crops, livestock and farmers against extreme climate phenomena such as rising temperature. However, we lack data to quantify the level of protection that trees provide. Our objective was to characterize the microclimate in different agroforestry systems under a Mediterranean climate to quantify the effect of trees on air and crop temperature. Air temperature above crop canopy for arable crops and in the fruiting zone of grapevine was measured with temperature and humidity probes in different agroforestry systems: (i) wheat in a 16-year-old poplar 13x6 m plantation and (ii) in a 21-year-old ash 13x2m plantation, (iii) arable crops (wheat, barley, pea, maize) in a 22, 23, 24 and 25-year-old walnut 13x8 m plantation, and (iv) grapevine in a 23-year-old stone pine 15x3m plantation.</p>	<p>Gosme, Marie          Dufour, Lydie          Dupraz, Christian</p>

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<p>Probes in agroforestry were placed in 6 points along a north-south transect in (i), 3 points along an east-west transect in (ii), 2 or 3 points along a north-south transect in (iii) and 5 or 6 points along a north-south transect in (iv), and in each plot's full sun control, along with measurements of solar radiation and, for pea and maize, crop temperature with thermistances inserted in the pods or stalks. Daily mean differences between agroforestry and full sun control were opposite between day and night, but with quite similar absolute values (figure 1): it was as much cooler in agroforestry during the day as it was warmer during the night, so that the sum of temperature was actually the same. These results raise questions about how microclimate, crop temperature and its effects on phenology are modeled in agroforestry simulation models.</p>	
<p><b>The role of small woody landscape features and agroforestry systems for national carbon budgeting in Germany</b></p> <p>The intensification of food production systems has resulted in landscape simplification, with trees and hedges disappearing from agricultural land, principally in industrialized countries. However, more recently, the potential of agroforestry systems and small woody landscape features (SWFs), e.g., hedgerows, woodlots, and scattered groups of trees, to sequester carbon was highlighted as one of the strategies to combat global climate change. Our study was aimed to assess the extent of SWFs embedded within agricultural landscapes in Germany, estimate their carbon stocks, and investigate the potential for increasing agroforestry cover to offset agricultural greenhouse gas (GHG) emissions. We analyzed open-source geospatial datasets and identified over 900,000 hectares of SWFs on agricultural land, equivalent to 4.6% of the total farmland. The carbon storage of SWFs was estimated at <math>111 \pm 52</math> SD teragrams of carbon (Tg C), which was previously unaccounted for in GHG inventories and could play a role in mitigating the emissions. Furthermore, we found cropland to have the lowest SWF density and thus the highest potential to benefit from the implementation of agroforestry, which could sequester between 0.2 and 2 Tg of carbon per year. Our study highlights that country-specific data are urgently needed to refine C stock estimates, improve GHG inventories and inform the large-scale implementation of agroforestry in Germany.</p>	<p>Golicz, Karolina Ghazaryan, Gohar Niether, Wiebke Wartenberg, Ariani C. Breuer, Lutz Gattinger, Andreas Suzanne R., Jacobs Kleinebecker, Till Weckenbrock, Philipp Große-Stoltenberg, André</p>
<p><b>Microclimate and water balance effects of temperate alley cropping systems at the field and landscape scale</b></p> <p>As climate change is expected to result in the increased occurrence of droughts and heatwaves, as well as extreme rainfall events in Central Europe, more resilient cropping systems are required. The inclusion of tree rows in agricultural land, i.e. alley cropping, could be a suitable strategy, as this has the potential to modify the microclimate and water balance of cropping systems. Here we present the available evidence from scientific literature on how temperate alley cropping systems affect the microclimate and water balance. Within the system, the tree rows generate gradients in light intensity, wind speed, air temperature and relative humidity, whereby strongest effects are observed in or close to the tree rows. Reduced light intensity through shading generally reduces crop yield, whereas beneficial effects of alley cropping on yield can be observed through a buffering of temperature extremes, increased water availability due to reduced crop evapotranspiration and enhanced infiltration, as well as a reduction in wind speed and surface runoff. There is a strong interaction between wind speed, air temperature, relative humidity and evapotranspiration, whereby the net effect is related to the design and orientation of the tree rows. It is also likely that the site context factors, e.g. local climate, surrounding landscape and topography, play a role in the microclimatic functioning of alley cropping systems. Furthermore, there could be effects beyond the agroforestry field, such as groundwater recharge and</p>	<p>Jacobs, Suzanne Bellingrath-Kimura, Sonoko Breuer, Lutz Grahmann, Kathrin Lüttschwager, Dietmar Niether, Wiebke Schwartz, Carmen Webber, Heidi</p>

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<p>moisture recycling. However, quantification of these effects is not possible due to insufficient evidence for temperate alley cropping systems. Therefore, future research should investigate the role of factors related to the site context in the functioning of alley cropping systems and quantify landscape-scale effects. The process understanding gained from those studies will contribute to designing alley cropping systems that enhance the climate change resilience of current temperate cropping systems.</p>	
<p><b>Methanogens and methanotrophs community dynamics during CH<sub>4</sub> flux hot-spots on riparian buffer systems in southern Ontario, Canada</b></p> <p>Riparian buffer systems (RBS) are a common agroforestry practice that consists of keeping a forested boundary adjacent to water bodies in agricultural landscapes, thus helping to protect aquatic ecosystems from adverse impacts, such as those caused by nutrient losses and soil erosion. However, despite the multiple benefits they provide, RBS can be hot-spots of methane (CH<sub>4</sub>) emissions due to the abundant organic carbon and high water tables in these soils. The rehabilitation of Washington creek's streambank in southern Ontario started 35 years ago with positive impacts in both terrestrial and aquatic environments, yet no studies have addressed the CH<sub>4</sub> cycling in this context. In this study, we look for hot-spots of CH<sub>4</sub> emissions, through longitudinal measurements of CH<sub>4</sub> fluxes from March to October 2018, in four contrasting RBS namely undisturbed natural forest (FOR1), coniferous forest (FOR2), rehabilitated agroforest (AGROFOR), grass buffer (GRASS), and an agricultural land (AGR). We used qPCR quantification and high-throughput sequencing from both DNA and cDNA profiles to target the activity and diversity of the methane-cycling communities in these soils. Our results suggest that hot moments of CH<sub>4</sub> emissions were only detected at the UNF site (<math>1232.62 \pm 167.68 \mu\text{g CH}_4\text{-C m}^{-2} \text{ h}^{-1}</math>), which were mainly associated with the high water content in these soils. Overall, methanogens were highly abundant in all riparian soils, including the genera <i>Methanosaeta</i>, <i>Methanosarcina</i>, <i>Methanomassiliicoccus</i> <i>Methanoregula</i>, but were mostly active in FOR1 soils. Methanotrophs community in AGR soils was comprised of members of rice paddy clusters (RPCs and RPC-1) and upland soil clusters (TUSC and USCα), different from all the riparian sites wherein <i>Methylocystis</i> was the most abundant taxon. Furthermore, at FOR1 site, despite the unfavourable conditions for methanotrophy, were found active methanotrophs from the class Alphaproteobacteria. Together, these results suggest that RBS at Washington creek are sinks of atmospheric CH<sub>4</sub>, except for the FOR1 that acts as CH<sub>4</sub> source presumably because of its high soil moisture content and abundant litter content and decomposition.</p>	<p>Obregon, Dasiel Mafa-Attoye, Tolulope Baskerville, Megan Mitter, Eduardo Oelbermann, Maren Thevathasan, Naresh Dunfield, Kari</p>
<p><b>Remote sensing techniques for calculating the above-ground biomass stored in agroforestry systems open the way for monitoring restoration policies</b></p> <p>Context: While many companies are seeking to offset their carbon emissions, following the resolutions of COP 26 in Glasgow, very few are financing carbon sequestration through enrichment of the above-ground biomass of traditional agroforestry systems in Africa. One reason is the difficulty of monitoring the effects of incentive policies on a large number of small-scale farmers in areas that are sometimes difficult to access. In the Sahelian Far North region of Cameroon, several projects encouraged the restoration of <i>Faidherbia albida</i> agroforestry parklands by subsidising their ANR (Assisted Natural Regeneration) from 1997 to 2008. A subsidy of about 0.2 USD was given to each of the farmers who kept a <i>Faidherbia</i> seedling or shoot in their fields, i.e., 20 USD ha<sup>-1</sup> for 100 trees per ha. An inventory of these parks in 2012 showed that about 1 million trees had been conserved. However, the security crisis of 2015 and restrictions related to Covid-19 have made it difficult for scientists to access these areas. Material and method:</p>	<p>Akodewou, Amah Palou Madi, Oumarou Peltier, Régis</p>

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<p>To verify the evolution of these agroforests after the end of the subsidy, a remote sensing study was carried out on the territories of two villages, Sirlawe and Gane, using Google-Earth images from 2009, 2013 and 2018. Results: The projected crown area more than doubled between 2009 and 2018, increasing from 246 to 587 m<sup>2</sup>*ha<sup>-1</sup> (2.5% to 5.9%) and from 245 to 575 m<sup>2</sup>*ha<sup>-1</sup> (2.5% to 5.8%) for Sirlawe and Gane, respectively. Discussion: The allometric equations for calculating the above-ground biomass of trees as a function of crown area remain too imprecise to make an acceptable calculation of the carbon stored during this period. However, it is very likely that the amount of above-ground biomass stored and pruned each year to feed livestock and produce wood energy cost much less than biomass obtained from plantations. Conclusion: Further work needs to be carried out by a European project INNOVAC, from 2022 onwards, to refine the remote sensing methods and the reliability of the allometric equations, which would pave the way for monitoring the quantities of carbon stored and saved by this type of ANR subsidy.</p>	
<p><b>Sustainability of Agro-Ecological Innovations in the Agro-Sylvo-Pastoral Systems of North Region of Cameroun: the Case of Highly Degraded Areas in South of Garoua</b></p> <p>The North region has received migrant population from the far North region during the drought episode of the years 1983-1984. From the year 1994, the region was saturated with migrants. To reduce the impact of the over growth of population on soil and vegetation, many projects had developed several agro ecological innovations, in particular agricultural production on plant cover, anti-erosion techniques, anti-erosion strips, stone cordon techniques, the combination of mineral and organic fertilizers, organic fern and crop association. Today, the situation is worrying because three-quarters of these innovations are not sustainable. The study intends to establish a transition to the sustainability of the agro ecological innovation in degraded areas of the South of Garoua dominated by an agro-sylvo-pastoral system. To achieve this objective, a literature review and interviews was conducted for actors and agro ecological innovations identification. Then, the SWOT tool was used to highlight the strengths and weaknesses of the actors in the provision of support services and accompaniment of the agro ecological innovations implemented. Finally, a synthesis grid of the actors' capacities to be strengthened in the field of agro-ecological innovations was used. The result shows that from 1994 to nowadays, 30 actors from the public sector and the private sector have developed several agro-ecological innovations in the study area. Therefore, a capacity building plan in technological, organizational, institutional innovation of the actors of agro ecological innovation has been proposed for a transition towards the sustainability of agro-sylvo-pastoral systems. The extinguish of agro ecological innovation at the end of project is due to a lack of strengthen of the innovation capacities of project actors and local actors. Derra et al. 2012 support this result by showing that weaknesses in the interactions of actors as well as limitations in the support and supervision services existing in the agricultural, forestry and pastoral sectors require the strengthening of the institutional and organizational environment. The construction of a innovation capacity building plant for the actors of agro-ecological innovation is a best solution for the durability of the agro-sylvo-pastoral resources.</p>	<p>Thierry Gaitan, Tchuenga Seutchueng Tchindjang, Mesmin Mathe, Syndhia Tata Ngome, Precillia Degrande, Ann</p>
<p><b>Do human activities lead to the destruction of mangrove ecosystems and climate change?</b></p> <p>Mangrove is a coastal forest typically tropical swampy coasts that have a relatively high rate of carbon sequestration. Due to the various activities carried out in the ecosystem, it is gradually degrading reason why the general objective was to evaluate the environmental impact of anthropic activities on trees diversity and</p>	<p>Armelle Verdiane, Tchanou Tchaptad Rene Bernadin, Jiofack Tafokou Zacharie, Tchoundjeu Patrick Bustrel, Choungo Nguekeng Bohdan, Lojka</p>

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<p>carbon sequestration potential of mangrove ecosystem. The study was carried out in two sites notably Manoka and Mbanga pongo in the Littoral region of Cameroon. In order to achieve our goal, six transects of 1000 m<sup>2</sup> were conducted to carry out floristic inventories to obtain structural and diversity parameters. While the destructive method of Chave for above-ground carbon biomass and household survey to determine the major activities in this ecosystem. Results revealed 828 individuals belonging to 21 species and 17 families with 78 % and 92 % of individuals in Rhizophoraceae mainly <i>R. mangle</i> (58 %; 60 %) and <i>R. racemosa</i> (21 %; 36 %) in Manoka's island and Mbanga pongo respectively. The degradation rate was calculated with the help of the number of present strains that resulted to 24.4 % and 17.8 % in Manoka and Mbanga pongo respectively. <i>Rhizophora mangle</i> which is the dominant specie is mostly used at 70 % to smoke fish which is the primary activity at Manoka and Mbanga pongo, 30 % for the construction of houses and canoes. Concerning carbon sequestration, we obtained 38.96 tC/ha and 48.99 tC/ha in Manoka and Mbanga pongo respectively. Due to the high rate of exploitation, the island is gradually disappearing and the population is suffering from flooding. Therefore, an efficient strategy will be delimiting a zone which will be considered as a protected area and encourage re-forestation of the specie which will lead to an increase in the quantity of carbon sequestered.</p>	
<p><b>Fight Climate Change by Planting the Right Seed in the Right Place</b> Agricultural production constitutes the main economic activity in Cameroon, a country with diverse climatic conditions and soils and constituting about 5 principal agro-ecological zones. Production systems too are quite varied, ranging from traditional systems to more modern industrial systems. All these variations result in a seed problem, especially among farmers of the traditional systems which is predominant. Seed farmers are poorly organised, cannot meet up with needs for improved seeds, and lack the capacity to properly handle and distribute seeds. Ignorance among farmers and poor access has maintained use of low quality seeds, poor seed application methods and low yields per hectare. PLANOPAC intends to create awareness among farmers on the importance of using appropriate seeds to improve upon productivity and fight climate change, and also encourage agroforestry alongside introduction of appropriate tree seedlings for use in the different agro-ecological zones. The proposed methodology would be; Lobbying for climate change considerations to be included in seed policy of Cameroon; Restructuring of seed production; Sensitisation of farmers on use of appropriate seeds and where appropriate; Training on tree domestication and agroforestry practices; Establishment of tree nurseries; Establishment of improved seed farms; Creation of resource centres. This project will result in the regular availability and use of improved seeds where appropriate. The fight against climate change will be reinforced through awareness creation on appropriate agroforestry practices and soil conservation from appropriate seed use. Improved seeds and introduction of high yielding varieties will result in high productivity and improved livelihoods. Seed distribution and application will consider proper management, ecological zones, soils, seasons and topography. It is expected that together with relevant International Organizations, the Government of Cameroon will step in to assist PLANOPAC in its effort to get farmers to fight climate change by planting the right seeds in the right place.</p>	<p>Kuh, Emmanuel Bakary, Bobo Kakambi, Gaelle</p>



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<p><b>Agroforestry as a natural climate solution</b></p> <p>Recently, agroforestry (AF) has received growing recognition as a promising natural climate solution (NCS) – an improved land-use practice that helps mitigate climate change. As a first approximation, it is clear that the addition of woody biomass on agricultural lands will provide additional carbon sequestration and storage. However, our review of the AF and NCS literature finds that the estimation and realization of the full potential of AF as a NCS requires that we resolve numerous scientific uncertainties. We summarize the state of the knowledge of AF as a NCS, delineate and discuss those uncertainties, and suggest paths for better constraining or resolving them. First, we address crucial questions about the definition and typology of AF, providing guidance on the discrimination of AF practices that can and cannot be considered as a NCS. Next, we review the state of carbon accounting in AF systems, highlight methodological shortcomings, and lay the ground for our forthcoming work that aims to provide significant improvements in this realm. We then discuss trends and challenges in efforts to map current AF adoption and future adoption potential, suggesting future directions for such work. Lastly, we contextualize NCS mitigation within the wider range of potential co-benefits and trade-offs of AF adoption, consider how the NCS perspective shifts the constraints and enablers of AF adoption and maintenance, and discuss outstanding needs for monitoring, reporting, and verification of new AF NCS projects. By crosswalking the realms of both AF and NCS sciences, our work aims to catalyze future research that can improve our understanding of the potential of AF as a NCS and help us make progress in realizing that potential.</p>	<p>Terasaki Hart, Drew Biswas, Tanushree Cardinael, Rémi Garcia, Edenise Kay, Sonja Lovell, Sarah Rosenstock, Todd Sprenkle-Hyppolite, Starry Stolle, Fred Suber, Marta Thapa, Bhuwan Wood, Stephen Yeo, Samantha Cook-Patton, Susan Beillouin, Damien Almaraz, Maya</p>
<p><b>The importance of trees for the adaptive management of Mediterranean wood-pastures</b></p> <p>Wood pastures play a crucial role in the provision of environmental services worldwide. Most of these systems, such as Mediterranean dehesa, are found on marginal land unsuitable for cultivation. Given their low productivity, the abandonment of wood pastures has increased markedly in recent decades. At the same time, in others wood pastures their use have been intensified. The ecological intensification may occur through livestock management or pasture improvement, with consequences on their adaptive capacity to a changing climate scenario still uncertain. This paper evaluates the impact of various management practices (abandonment of grazing, continuous grazing, rotational grazing and pasture improvement) on the performance and production of Mediterranean wood pastures, as well as the role of trees as a stabilising element. The response in production, functional diversity and carbon fluxes beneath and beyond trees located in an aridity gradient is shown. This work evaluates whether management effects depend on climatic conditions and the presence of trees, in order to predict future responses of wooded pastures to changing climatic conditions.</p>	<p>Carrascosa, Alejandro Moreno, Gerardo Frade, Cristina Igual, Jose M. Rodrigo, Sara Valverde, Angel Rolo, Victor</p>
<p><b>Smallholder agroforestry and agroecology extension: the foundation for a just transition to a viable world food system</b></p> <p>According to the UN, net annual carbon must be reduced by 15 gigatons to reach the target of keeping global temperature increase below 1.5°C and maintain the viability of planet earth for human society. While low emission energy and other widespread changes are necessary to achieve this goal, they'll take significant time and expense. Our global food system is responsible for about half of greenhouse gas emissions, but small farms also could play a major, initial role averting the worst of climate chaos. For 25 years, Sustainable Harvest International (SHI) has provided individualized, intensive agroforestry and agroecology training to over 3,000 smallholder farm families in Central America. Each family has restored an average of 3.25 hectares of previously degraded land through agroforestry and</p>	<p>Reed, Florence</p>

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<p>agroecology practices including the planting of 1,000 trees and, over ten years, sequestering 160 tons of CO<sub>2</sub> in trees and soil. At the same time, they each provide food security and increased income for five people previously living with food insecurity and poverty. Collectively they've restored 12,000 hectares, including the planting of 4 million trees. Years after graduating from the program, 91% of families still maintain agroforestry and agroecology systems. Eighty percent of humanity is fed by 500 million smallholders, who predominantly farm degraded land with little or no access to agroforestry and agroecology training. Based on 25 years of experience, SHI believes they'd embrace building a better quality of life through agroforestry and agroecology when provided with adequate technical assistance. In so doing, they could collectively sequester 8 gigatons of CO<sub>2</sub> per year (40% of the UN goal) for at least ten years. At the same time, they'd increase soil fertility, improve public health, secure food sovereignty, reduce global strife, and protect water sources. The cost would be a fraction of current farming subsidies.</p>	
<p><b>Effect of different phosphorus application rates on nitrous oxide emission in nitrogen fertilized switchgrass (<i>Panicum virgatum</i> L.)</b></p> <p>Mangrove is a coastal forest typically tropical swampy coasts that have a relatively high rate of carbon sequestration. Due to the various activities carried out in the ecosystem, it is gradually degrading reason why the general objective was to evaluate the environmental impact of anthropic activities on trees diversity and carbon sequestration potential of mangrove ecosystem. The study was carried out in two sites notably Manoka and Mbanga pongo in the Littoral region of Cameroon. In order to achieve our goal, six transects of 1000 m<sup>2</sup> were conducted to carry out floristic inventories to obtain structural and diversity parameters. While the destructive method of Chave for above-ground carbon biomass and household survey to determine the major activities in this ecosystem. Results revealed 828 individuals belonging to 21 species and 17 families with 78 % and 92 % of individuals in Rhizophoraceae mainly <i>R. mangle</i> (58 %; 60 %) and <i>R. racemosa</i> (21 %; 36 %) in Manoka's island and Mbanga pongo respectively. The degradation rate was calculated with the help of the number of present strains that resulted to 24.4 % and 17.8 % in Manoka and Mbanga pongo respectively. <i>Rhizophora mangle</i> which is the dominant specie is mostly used at 70 % to smoke fish which is the primary activity at Manoka and Mbanga pongo, 30 % for the construction of houses and canoes. Concerning carbon sequestration, we obtained 38.96 tC/ha and 48.99 tC/ha in Manoka and Mbanga pongo respectively. Due to the high rate of exploitation, the island is gradually disappearing and the population is suffering from flooding. Therefore, an efficient strategy will be delimiting a zone which will be considered as a protected area and encourage re-afforestation of the specie which will lead to an increase in the quantity of carbon sequestered.</p>	<p>Osei, Augustine Gabbanelli, Nadia Oelbermann, Maren</p>
<p><b>Genetic modulation of stomatal aperture regulating genes to enhance carbon gain and yield in <i>P. deltoides</i></b></p> <p>Globally increasing carbon dioxide is impacting the carbon residential potential and sequestration capacity of trees resulting into yield loss. Usually, the trees adapt to stress conditions by limiting stomatal opening that reduces CO<sub>2</sub> uptake, affecting yield and productivity. The research objectives were framed to assess CO<sub>2</sub> conductance of <i>P. deltoides</i> plantations in different geographical locations and modulation of stomatal aperture regulating genes through CRISPR/Cas9 technology. The ANOVA on morphological and physiological parameters revealed significant difference among all the sites for most of the traits except LA. The mean performances showed that stomatal conductance (gs; 0.322±0.02) was directly and positively associated with the yield traits i.e, tree height (TH; rg= 0.507; p&lt;0.000) and diameter at breast height (DBH; rg =0.869; p&lt;0.000). Further,</p>	<p>Thapliyal, Garima Bhandari, Maneesh S Vemanna, Ramu S Yadav, Shobhna Pant, Manu Chandrashekar, Babitha K Singh, Hukum Barthwal, Santan</p>



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<p>genetic estimates specific, heritability coupled with high genetic advance (GA % of means) were also revealed by gs (Hb2 =95.86; GA=84.25) and photosynthetic rate (Hb2 =95.71; GA=65.33) showed that selection could be conducted for these traits in natural plantations. Based on these results, multiplexing guide RNAs (gRNAs) were designed and successfully cloned, to target guard cell specific anion channel encoding ALMT12 and SLAC1 genes of <i>P. deltoids</i>, to improve CO<sub>2</sub> uptake and enhance timber yield through CRISPR/Cas9 technology. After downregulation of anion channel encoding genes, the stomatal turgidity and guard cell behaviour in model species <i>P. deltoides</i> will be assessed.</p>	
<p><b>Scaling up estimates of windbreak carbon sequestration in the central United States</b></p> <p>Globally, agroforestry is recognized as one of the key agricultural land management strategies that can sequester carbon while providing other key services as the climate changes (IPCC, 2019). These systems offer two advantages for storing carbon in agricultural landscapes: 1) they offer high carbon storage capacity on a compact footprint while enhancing adjacent land practices, and 2) carbon is sequestered for a longer period of time compared to surrounding land uses, such as annually-harvested crops or grasslands. However, there are several well-documented challenges when it comes to estimating the amount of carbon sequestered by agroforestry, one of which is an insufficiency of data on the location and extent of these practices. In the United States, map products created via a partnership between the U.S. Forest Service Forest Inventory and Analysis (FIA) program and the USDA National Agroforestry Center (NAC) offer a partial solution by providing high-resolution datasets of one of the more common agroforestry practices in the central United States: windbreaks. These spatially detailed datasets have been produced for the states of Nebraska and Kansas. We combine these datasets with field-based sample plots in order to produce first-order estimates of carbon sequestered by windbreaks over an area of interest. To provide context, estimates for windbreaks are aggregated to Nebraska and Kansas and compared to carbon sequestered by forest land in the same states. We also investigate enhancing estimates using lidar data for a smaller-scale pilot study. Lessons learned from this effort may be applicable to other countries conducting assessments of carbon sequestration in agroforestry practices.</p>	<p>Kellerman, Todd Liknes, Greg Bentrup, Gary Meneguzzo, Dacia</p>
<h3>E. Transitioning to Food Security and Health</h3>	
<p><b>Sustainably feed humanity by meeting its current needs without compromising future generations with locally adapted agroforestry</b></p> <p>Agroforestry refers to a sustainable land management system that increases total production, combines agricultural crops, trees, forest plants and/or animals simultaneously or in sequence, and implements management practices that are compatible with the culture of local populations (references). As the use of fertilizers and pesticides is currently being questioned, scientists must turn their research to substitutes or complements of these products to achieve sustainable food security. RESEAU BURUNDI 2000 PLUS as a local NGO very active in the conception, research and implementation of food security programs, agroforestry has become a priority in its programs with an increased sensitivity of its donors and funders. In 2019, IFDC has made a collection of more than 50 medicinal plants used in the traditional practices of Burundi in bio fertilizers and bio pesticides. RESEAU BURUNDI 2000 PLUS Network has already tested at least 8 of them including tobacco, neem leaf and seeds, ash, basil, garlic, papaya leaves,</p>	<p>Réseau Burundi2000plus, Réseau Burundi2000plus</p>

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<p>lemongrass, Orthia, Tithonia and moringa (bio activator) and extension in rural areas is underway. The trials were conducted in rural areas in farmers' plots and focused on the comparative effectiveness of bio fertilizers and chemical fertilizers on maize and vegetable crops and the control of diseases and pests by bio pesticides. The result was comparable yields of these crops for both types of fertilizers. The proposed agroforestry is articulated on the integration of the agroforestry system based on trees and plants with multiple uses. It is around these exchanges that we call upon the scientific community to cooperate in order to sustainably feed humanity.</p>	
<p><b>Proposal of an innovative analysis framework of plant health management practices for the design of sustainable cocoa-based agroforestry systems</b></p> <p>The concepts of integrated approaches of health are based on an integrative conception of knowledge and action strategies in the domains related to the health of humans, animals and the environment, including plants. This integrative conception refers to "One Health" approaches in order to understand the issues related to health in relation to the multiplicity of variables that build them but also in relation to the systemic dynamics that make them interact. Applied to cropping system, these concepts lead us to have a double perspective on it: (i) as complex biophysical systems with its different compartments and components in permanent evolution under the influence of pedoclimate and techniques, and (ii) as an object of implementation of farmers' rationales that can be described in decision-making systems. We propose to explore the potential of activity analysis, which considers practice as a dynamic of asymmetric interactions between a farmer and his environment, for the study of plant health management in cocoa-based agroforestry systems. Farmers experiment different ways of understanding the health of their agro-ecosystems. The cultural heritages and farming experiences of each farmer shape their management of the agroecosystems and thus the resulting practices in terms of pruning, choice of species and varieties, use of inputs, and many other practices. This original paper aims to propose an innovative analytical framework based on a systemic approach for the analysis of plant health management practices at the agroecosystem scale. Taking into account such an approach to foster the design of "healthy" agroecosystems would constitute a major advance.</p>	<p>Allinne, Clémentine Notaro, Martin</p>
<p><b>Agroecological transition via agroforestry, a leverage to strengthen family food security. Northern Haiti case</b></p> <p>Tropical agroforestry systems are ancestral in Haiti. From the colony until today, this system has known great changes in its composition, its diversification and its functions. This system continues to occupy a prominent place in the strengthening of agrifood value chains and adaptation to climate change. Agroforestry production is a profitable activity in the Northern Haiti and contributes to reducing the environmental vulnerability of communities. This production is done with a view to agroecological transition and income-generating activity. The objective of the study is to highlight the contribution of agroforestry products in determining the living income of families and to determine the effects of agroecological practices on resilience to environmental shocks. The study was carried out on a sample of an agroforestry system by making use of the available information. Additional data has been collected and analyzed. The results reveal that agroforestry products contribute to more than 25% in the composition of the living income of farms and to 34% of the income derived from agriculture. The analysis confirms the great diversification of tropical agroforestry systems with 50 species that can be used for self-consumption by families and medicinal plants. The central role of agroforestry systems in the functions of food self-sufficiency and important sources of income is highlighted on farms. The function of plant</p>	<p>Theliar, Maxim Jean Denis, Sardou</p>

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<p>barrier and stabilization of watersheds by good agroecological practices was also demonstrated by the results of the study. The tropical agroforestry system fulfills multiple functions on farms. The study reveals the important contribution of the system in the 4 dimensions of sustainable food and nutrition security.</p>	
<p><b>Endogenous silvicultural / fruit- growing agroforestry practices, food crops and reforestation around Togodo- sud National Park in Togo to fight against climate change</b></p> <p>Introduction : In Togo, the association of agroforestry with food crops is poorly developed. Population growth, the need for cultivable land, timber and energy are often a source of intense anthropogenic pressure on national reserves and parks in sub-Saharan Africa. To spare the Togodo-Sud National Park (PNTS), located in the south-east of Togo from this scourge, one NGO lobbied to have the populations of the neighboring cantons retrocede to PNTS, 3000 ha of cultivable land. During the development of these lands by the farmers, the NGO sensitized the populations to opt for what it calls "Endogenous Sylvicultural and Fruit-growing Agroforestry Practice in association with Food Crops to promote Reforestation" (PAESF/CV/Ref). This study presents the results of ten years of implementation of the PAESF/CV/Ref by the operators of the canton.</p> <p>Methodology : Survey and geospatialization of the operators and exploited surfaces, counting and taking of images of the preserved and/or planted species, were the study methods. Results : On of 33.0546 ha valued by a sample of 31 farmers, 58 forestry and fruit species have been identified in association with food crops. Corn, cassava, beans, yams and pigeon peas were the most important food crops grown in association with <i>Kahya gradifiliola</i> (Fig 1), <i>Ceiba patrenda</i>, <i>Agnogeisus leocarpus</i>, <i>Adansonia digitata</i>, <i>Manguifera indica</i> (Fig, 1) and <i>Citrus aurantium</i>. Brought back to 449.1844 ha of cultivated land by the 339 farmers in this canton, estimates indicate the preservation of 7882 plants by endogenous Agroforestry is on-going. These results prove that PAESF/CV/Ref is a reliable agroforestry method that can be tried everywhere else. Discussions: The forest species cultivated on the cultivated retrocedes of Togodo-sud lands are listed but not exhaustively. Further study is essential. Conclusion : This assessment is in the process of being extended to all the cultivated areas of the 3000 ha retroceded.</p>	<p>Dahounom, Azizou Aboudou Koudouvo, Koffi Edah, Koffi Agbani, Onodjè. Pierre Komlavi, Esseh Agbani, Onodjè. Pierre Apolline, Reboud Aguidissou, Nestor Oscar Téfé, Yawo Gbéassor, Messanvi Amouzou, Kokou Noété</p>
<p><b>Impacts of Agroforestry conservation practices on soil health, crop nutrients and safety in Zambia</b></p> <p>Soil health and crop nutrition could be improved through incorporation of leaf biomass of leguminous trees such as <i>Gliricidia sepium</i> in alley cropping systems. To support this, a multi-disciplinary <i>Gliricidia</i> project was established by involving smallholder farmers in two maize growing districts in Eastern Zambia. A common practice in the study area is mulching using <i>Gliricidia</i> leaf biomass. A combination of maize-legume-agroforestry conservation practices with <i>Gliricidia</i> could provide multiple benefits and reduce risks to smallholders. The ongoing project established field trials in 15 sites with seven treatments (T) that included <i>Gliricidia</i> intercropping with maize, soybean and groundnuts and control (sole crops). For the last two growing seasons, crop and soil samples were collected and analysed for: i) nutritional, anti-nutritional, functional, and mineral properties, as well as mycotoxin (aflatoxin and/or fumonisin) and <i>Aspergillus</i> load (crops); and ii) soil nutrients and microbial loads. The treatments with intercropping of <i>Gliricidia</i> (T1, T4, T5) showed in general higher ash, total carbohydrate, starch, amylose, crude fibre contents than the controls: sole maize (T2 with fertilization, T3 without fertilization), soybean (T6) and groundnuts (T7). <i>Gliricidia</i> intercropping significantly (<math>p &lt; 0.05</math>) reduced the tannin and phytic contents in soybean, groundnuts, and maize grains. Better functional properties were observed in treatments with <i>Gliricidia</i>. Moreover, <i>Gliricidia</i> increased level of nitrogen</p>	<p>Njoloma, Joyce Prisca Alamu, Emmanuel Oladeji Akello, Juliet David, Chikoye Nyoka, Betserai Isaac Dale, Lewis Chazangwe, Ray Tesfai, Mehreteab Nagothu, Udaya Sekhar Ngumayo, Joel</p>

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<p>contents in the grains, resulting in increased protein contents (see the figure). Gliricidia incorporation had minimal effect on the occurrence and distribution of <i>Aspergillus</i> spp. in the soils and crops. Overall, treatments with Gliricidia recorded lower mycotoxin prevalence, while sole maize (T3) registered the highest mycotoxin prevalence. The total organic carbon stocks in the soils ranged from 17.6 - 25.6 C t/ha leading to improved soil fertility. Various multimedia platforms including social media were used to disseminate information on Gliricidia agroforestry practices and its benefits to farmers and other stakeholders.</p>	
<p><b>Performance of black gram (<i>Vigna mungo</i> L. Hepper) under fruit tree-based agroforestry systems</b>  The study entitled “Performance of black gram (<i>Vigna mungo</i> L. Hepper) under fruit tree based agroforestry systems” was carried out at experimental farm of Department of Silviculture and Agroforestry, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan- 173230 (HP), India. The experiment was laid out in RBD (factorial) with three replications. The study aimed at exploring the possibilities of successful cultivation of <i>Vigna mungo</i> as intercrop under different fruit based agroforestry system and in open conditions. The experiment comprised of 5 treatments viz., T1: RDF, T2: FYM, T3: VC, T4: Jeevamrut and T5: no manure under four different systems viz. peach, apricot and pear based agroforestry systems and sole crop for two consecutive years. Among, different doses of fertilizers, growth and yield parameters of black gram i.e. plant height (45.89cm), number of primary branches (5.28), number of pods per plant (28.74), number of grain per pod (7.27), dry matter per plant (4.46), test weight (33.82g), economic yield (5.57q/ha), straw yield (17.41q/ha) and biological yield (22.98q/ha) were found maximum with the application of recommended dose of fertilizer. Soil physico-chemical properties were found to be improved under tree canopy as compared to outside canopy. All organic manures generally improved the physical and chemical properties of soil which in turn enhanced the growth and production of black gram under different agroforestry system as well as in sole crop. Use of organic manures increased the availability of nutrients to the plant. The maximum net return (19108.06 Rs/ha) and gross return (53277 Rs/ha) was obtained when recommended dose of fertilizer was used under peach based agroforestry system. The findings of present study suggested that cultivation of black gram in combination under different fruit trees may be recommended for better economic returns.</p>	<p>Sharma, Dr Shivani  Thakur, Dr Chaman Lal  Bhardwaj, Dr Dr</p>
<p><b>Integrating high value trees in homesteads for food, nutrition, and income security: the case of Lemo district, Southern Ethiopia</b>  To address the multifaceted problems including food and nutrition insecurities, we introduced high value improved varieties of <i>Persea americana</i> Miller (avocado), namely Ettinger B, Fuerte B, Hass A, Nabal B and Reed avocado cultivars, in Lemo district, Southern Ethiopia. We followed participatory on farm trials and evaluated their performance under different bio-physical and socio-economic contexts, and assessed their role for food and income security. We selected 77 households, including male and female headed households from two districts (Kebele), namely Upper-Gana and Jewe kebele. The project provided six seedlings to each participant. The planted seedlings were fenced and tagged. Survival and growth performance of the planted seedlings was monitored at three-month intervals. Evaluation of their survival showed no significant difference between the two study sites. Avocado varieties began to produce fruit within 2 to 4 years, with significant differences among varieties. Significantly highest mean fruit load was recorded for Nabal B (281 fruits per tree) followed by Hass (249 fruits per tree). We found positive correlations between fruit load and crown diameter for each cultivar, and stronger for Ettinger (<math>r = 0.7</math>), and Nabal B (<math>r = 0.64</math>). Nabal had</p>	<p>Gebre Kirstos, Aster  Seid, Hadia  Mokria, Mulugeta  Hagazi, Niguse  Hadgu, Kiros  Dubale, Workneh</p>

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<p>commercially valuable large fruit and higher yield. Farmers preferred the test of Hass variety. 80% of the fruit yield used for house consumption and 20% for sale, a household could generate income of 3000 Birr per year. Especially, farmers realized the importance of having fruit trees in their homestead during the COVID pandemic. In general, the adoption rate of the improved avocado varieties was very high. Participatory research and effective partnerships with the farmers played a role in their adoption. Due to their excellent performances and high rated evaluations by farmers and partners, there is high local demand to scale up within and beyond the current project intervention sites. We recommend future projects to address some of the existing challenges including, but not limited to unavailability and inaccessibility of quality germplasm at a required quantity and limited technical knowledge and skills in propagation and management techniques.</p>	
<p><b>Transition of cereal-based system to high value nutritive food-based agroforestry system in north-western India</b></p> <p>Intensive management practices followed in rice-wheat crop rotation have adversely affected the natural resources leading to the need for sustainable and economically viable system. Commercially recommended varieties of different high value vegetable crops such as turmeric, colocasia, onion and potato were evaluated under different aged poplar plantations. Most vegetable crops are photo-thermo sensitive and their planting time varies in different regions. Among the six onion cultivars (POH-1, PYO-1, PWO-2, PRO-6, PRO-7 and Pb Naroya), PRO-7 transplanted in mid-December produced maximum bulb yield (27.59 t ha<sup>-1</sup>) under poplar. LAI and PAR values indicate that PRO-7 is a short duration cultivar which matures in end-April before the poplar canopy becomes dense. Net Present Value and Annuity Value of poplar + onion system was 28 per cent higher than the poplar + wheat model. Likewise, among six potato cultivars (K. Pukhraj, K. Badshah, K. Jyoti, K. Pushkar, K. Chipsona-1 and K. Chipsona-3), the highest average yield (30.9 t/ha) was obtained in cultivar K. Pukhraj when planted in mid-November in poplar plantation. Colocasia sown on ridges with 25 per cent additional seed and fertilizers than recommended doze produced significantly higher yield as compared to crop sown on flat beds. Among ten turmeric cultivars, SD-3 produced the highest yield under poplar. Under poplar, an average increase of 5.7 per cent curcumin content was recorded as compared to open conditions. Return of nutrients through poplar litter fall (20 t) improved the soil organic carbon, available N, P and K in poplar plantation which were higher by 32.3, 14.2, 52.1 and 7.9 per cent, respectively in surface layer after six-year rotation as compared to pure cropping system. Thus, under intercropping system, suitable cultivars combined with appropriate planting time and management practices improve productivity potential of intercrops essential for sustainability and economic viability of cropping systems.</p>	<p>Gill, Rishi Kaur, Navneet Singh, Baljit Dhatt, Ajmer Bhardwaj, Ankita Singh, Prabhjot</p>
<p><b>Investigating the Impact of Urban Homegardening on Households' food and Nutritional Security in response to the Covid-19 Pandemic</b></p> <p>The study aims to visualize a comparative food and nutritional security of COVID19 vulnerable families who possess homegardens and who do not possess homegardens. Thus, the first objective is set out to understand different coping mechanisms adopted by high risky areas families during the COVID19 lockdown period and to compare the economic resilience nature of those who possess homegardening with those who do not possess homegardening in Seethawaka divisional secretary area in Colombo, Sri Lanka. Further, the next objective is set out to understand different types of homegardening practices adopted by households during the COVID 19 lockdown period and to understand the level of government support for their homegardening intervention. A structured survey</p>	<p>Hewawasam, Madushika Karthigesu, Jeyavanan Muraleetharan, Anusiya</p>



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<p>was done through in-person discussion, focus group discussion and observations about the homegardening. Primary data collection was used to gather reliable information about homegardening in the area. Secondary data was also gathered to get a clear understanding of the research problems. Quantitative data were collected via a survey questionnaire with close-ended questions. Further, open-ended question was also used to gather qualitative data. Quantitative data analysis is done by using SPSS software and MS Excel software in a meaningful data presentation view. Almost all responded households grow plants in their homegarden. Some of them were continued post-Covid-19. Comparatively, the majority of households grow vegetables, fruits and medicinal plants in the homegarden which is helpful to carry out day to day family consumption. About 81.7% of household thought usefulness of homegardening to manage household expenses. 55% of households were interested to grow vegetables and 23.3% of households were continued to grow post-Covid-19. 80% of householders saved money from homegardening and 73.3% of householders could manage the stress level of the whole family during curfew time at Covid-19. 93.3% of householders appreciated the tasty of homegarden vegetables and fruits. 83.3% of householders could be able to increase nutritional level after consuming homegarden grow fruits and vegetables.</p>	
<p><b>Visitation and use of Tropical forests along a gradient of land use intensification</b> Tropical forests play important roles in the food security and health of millions of people, yet access to, and use of, non-timber forest products (NTFPs) may be compromised as tropical forests undergo land use intensification. Because land change in tropical forests is globally extensive and highly dynamic, long-term assessments of forest dynamics and pan-tropical comparisons of forest use are urgently needed. We asked two key questions: 1) Are gradients of land use intensification associated with different forest visitation patterns? 2) Does NTFP collection vary along these gradients? Seven tropical, low-income countries across three continents were selected. Three zones along a gradient of land use intensification were defined within each country. We surveyed 1,823 households to assess forest visitation and forest products collection. Landsat images from three time periods between 1985-2015 were used to summarize forest and land cover trends surrounding households. Mixed effects modeling was used to explore forest visitation and four measures of NTFP collection along land use intensification gradients and forest change. The diversity of forest products collected, as well as the likelihood of both households collecting construction materials and routinely visiting forests, declined with land use intensification. The land use intensification gradient was not included in models that best predicted the likelihood of forest foods and fuels collection. At least one metric of long-term forest dynamics was significantly associated with forest visits, forest richness, and collection of foods, construction materials, and fuels. These results demonstrate the importance of differentiating among NTFP types in analyses of forest use alongside landscape change. Furthermore, this study indicates the significance of incorporating temporal dimensions of forest cover and structure when asking these questions. Long-term trends in land use intensification and forest dynamics are important in explaining use of tropical forests, and their consequent potential contributions to food security.</p>	<p>Fromstein, Maya Gergel, Sarah Tomscha, Stephanie Sunderland, Terry</p>

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<p><b>The GAIN project: intercultural models for nutrition and health of indigenous populations through gender-sensitive agroforestry practices in Peru</b></p> <p>A quarter of the Peruvian population is native to one of the 55 indigenous groups present in the country, 51 of which live in the Peruvian Amazon. In this area, over half of indigenous children under 5 years old suffer from chronic undernutrition and anaemia, far above national average. High levels of poverty, food insecurity and child mortality and morbidity still persist amongst indigenous peoples in Peru. The health systems of the diverse indigenous populations of the Peruvian Amazon are based on an integrated understanding of the world, whereby forests support plant and animal biodiversity, provide adequate resources for good nutrition and health and hold significant cultural value. For these Amazon-dwelling populations, agroforestry is the closest agricultural practice to traditional indigenous ways of life because it supports high levels of cultivated and non-cultivated biodiversity. There is limited evidence of the impacts of agroforestry on human nutrition and health and, to date, inter-disciplinary research integrating agroforestry, nutrition and health has not been done in the Peruvian Amazon. In this context, the GAIN project has been funded since 2019 by Fondecyt (Peru) and the Newton Fund (UK) and seeks to co-design culturally-appropriate and gender-sensitive agroforestry options and food-based recommendations that have the potential to sustainably improve nutrition and health of indigenous populations in the Peruvian Amazon. Its use of intercultural models represents a major step change in the development of approaches to address chronic undernutrition and high anaemia prevalence in indigenous populations, and buffer them against future nutrition and health shocks. Based on an evidence-led approach, the GAIN project documents how socio-cultural norms, gender dimensions and the food environment mediate the multiple pathways through which agroforestry practices contribute to maternal and child nutrition and health. Understanding these dynamic processes is essential to ensure intercultural nutrition and health interventions are effective.</p>	<p>Katic, Pamela Mercier, Sabine Carrasco Vera, Miluska Flores Rojas, Maria Ximena Chichipe Puscan, Ariel Kedy Del Castillo Torres, Dennis Rengifo Salgado, Elsa Jimenez Yoplac, Geidy Yecenia Seminario Namuch, Gerardo Pesantes Villa, Maria Amalia Bazan, Mariella Deheuvels, Olivier</p>
<p><b>Management of an agroecosystem by 'Grupo de Trabajo Vícam T.Y.', in Sonora, Mexico</b></p> <p>The Yaqui communities are located in the south of the state of Sonora, in Mexico; the Green Revolution began in this region, which resulted in increased yields of basic grains, mainly wheat; however, monoculture has been a reason for exclusion for the most vulnerable population, including the Yaqui ethnic group. In addition, local research centers promote technological packages without considering the impact on the environment or respect for local biodiversity. Therefore, some community organizations look for options to obtain healthy and safe food that respects the environment, resulting in a field managed with agroecological principles and that integrates plants from the native vegetation. The objective of the work is to describe some of the agroecological indicators of the productive ecological dimension applied in the farm of Grupo de Trabajo Vicam T. Y. through a case study. The group has an area of 1.1 ha; on the farm, areas have been established for planting vegetables and basic grains, planting forage, establishing fruit trees, planting cuttings of native plants, preparing compost and organic fertilizers, preproduction of seeds of native species in germination trays, cultivation of medicinal plants and a barnyard for the rearing and fattening goats. The external inputs applied on the farm have been reduced over time, the prices of the products are not affected by variations in the market since the purpose of production is not marketing and because the group exchanges them for other products. goods in the same community, the family participates in farm management activities, and the language and religious rites, typical of the ethnic group, are tried to maintain and reproduce. To cultivate plants and to achieve the</p>	<p>Montes-Rentería, Rodolfo Gomez-Martínez, Emanuel Ramírez-García, Adán Guillermo</p>



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<p>propagation of species, the group has put into practice the overlapping knowledge: local and scientific.</p>	
<p><b>Agroforestry system compared to a monoculture in the Yaqui Valley</b>  The Yaqui Valley was considered one of the most fertile and productive regions in the entire country and was cataloged as the granary of Mexico for its high volumes of wheat production, mainly. However, the relationship of balance and harmony that existed between nature deteriorated due to the excessive use of chemical agents introduced into biological systems and the pollution of air, water and soil derived from the development of the Green Revolution. In this context, Don Jesús Higuera, a 65-year-old farmer, took the initiative to practice a diversified farming system using organic inputs, economically profitable, with high yields, minimal environmental impact and using native vegetation plants. The objective of this work is to report, under the principles of sustainability, the evaluation of the diversified system versus the wheat production system. The methodology applied was the Framework for the Evaluation of Natural Resources Management Systems that incorporates Sustainability Indicators. The result indicates that for each peso invested in growing wheat, 32 cents (mexican currency) are recovered and for the diversified system practiced by Don Jesús, the recovery is equivalent to 968%. In addition, in the diversified crop there are 17 plant species: most are for personal consumption, 4 economically profitable crops. So, the teaching of Don Jesús is that the benefits obtained by the producer with this diversified system go beyond economic goods. The intangible assets obtained in the diversified farming system are essential for the good life of society: the price of the products is accessible to the most vulnerable population, obtaining good quality products for private consumption and, in the future, transforming raw materials into by-products.</p>	<p>Ramírez-García, Adán Guillermo</p>
<p><b>Growth and yield responses of pea (<i>Pisum sativum</i>) to various organic inputs in <i>Grewia optiva</i>-alley cropped system in NW Himalayas</b>  Tree-crop interactions studies and organic manures can be used to develop ecologically and economically resilient land use ecosystems. Therefore, an on-field experiment was undertaken at experimental farm of Department of Silviculture and Agroforestry, Dr. YSP, UH&amp;F, Solan during the Rabi season, 2020 in <i>Grewia optiva</i> alleys. The experiment was conducted in split-plot design with tree spacings [10 m ' 1 m, 10 m ' 2 m, 10 m ' 3 m and sole cropping] as main plot, under which pea crop was grown with six organic fertilizers [Control, FYM equivalent (equiv.), Vermicompost (VC) equiv., Jeevamrut equiv., FYM + VC equiv. and recommended dose fertilizers] as sub-plot, each replicated thrice. Planting of <i>grewia</i> as an agroforestry intervention at a spacing of 10 m× 1 m yielded markedly higher amount of stem, leaf, branch total biomass as well as carbon stock. Intercropping of pea under the spacing of 10 m × 3 m of <i>grewia</i> trees alleys yielded significantly highest pea crop yield (57.25 q ha<sup>-1</sup>). Similarly, application of FYM gave significantly higher yield than control, RDF and other organic sources of fertilisers. Bulk density, organic carbon, available N, P, K content improved significantly under agroforestry system than sole cropping. Similarly, application of FYM, vermicompost, FYM+VC and RDF also enhanced the physico-chemical status of the soil than control. Overall, the study concluded that the intercropping of pea under wider spacing (10 m × 3 m) of <i>grewia</i> trees and application of FYM generate the best synergetic effect. The total carbon storage capacity (biomass plus soil) enhanced considerably under <i>grewia</i> based agroforestry intervention than sole cropping. Raising of pea under 10 m × 1 m spacing of <i>grewia</i> and application of FYM gave maximum returns (US \$ 2, 137) on per hectare basis and high benefit cost ratio (2.4).</p>	<p>Keprate, Alisha  Bhardwaj, D.R.  Thakur, C.L.  Kaushal, Rajesh  Sharma, Prashant  Kumar, Dhirender</p>

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<p><b>Accessibility of ecosystem services: relationships between forest succession, fragmentation, and food security</b></p> <p>In this study, we aim to explore the impact of forest successional stage and degree of fragmentation on the food security of communities reliant on the Mau forest in Narok, Kenya. Specifically, we investigate two research questions with regard to fruit, vegetable, and woodfuel: (1) Does the capacity of forests to produce ecosystem services (ES) differ amongst forests of varying ages and fragmentation?, and (2) Does the accessibility of ES differ amongst forests of varying ages and fragmentation? Firstly, historical aerial photographs are used to identify forests of varying ages across the Mau forest landscape, while high spatial resolution imagery is analyzed to measure forest fragmentation. With this information, we examine forests of varying ages along a gradient of fragmentation. The capacity for forests to produce woodfuel is estimated using the Woodfuel Integrated Supply/Demand Overview Mapping (WISDOM) model. We use interviews to quantify beneficiaries' collection of woodfuel, fruit, and vegetables from forests. Participatory mapping exercises are implemented to record the location from which each ES is obtained, as well as the route travelled to retrieve it. This spatial information is used to inform the ways in which beneficiaries accessed each ES, and whether or not factors other than proximity influence accessibility. Finally, we conduct statistical regression analyses, whereby ES production and ES accessibility is examined as a function of forest age and the degree of forest fragmentation. We expect to see a mismatch in terms of where ES are most produced and where they are most easily accessed. With information regarding the influence of forest age and fragmentation on ES delivery, strategies regarding the conservation and restoration of forests and agro-forests can be developed in a way that not only provides ecological benefits, but also supports local food security and ensures sustainable ES use.</p>	<p>Ng, Aeryn Gergel, Sarah</p>
<p><b>Ethnobotanical study of food plants used in traditional medicine in the canton of Sédomé, bordering the Togodo-Sud National Park, District of Yoto in Togo</b></p> <p>Food plants contain active ingredients endowed with various medicinal properties which can be involved in the treatment of many diseases. The population of the canton of Sédomé, a locality bordering the Togodo-Sud National Park (PNTS) (District of Yoto in Togo), uses a diversity of plant species but little scientific work has been done on this environment. This study is devoted to the inventory of plants and plant recipes with nutritional and therapeutic potential in Sédomé, with the aim of enhancing the value of these plants. From March to September 2020, an ethnobotanical survey, based on the use of individual interviews using a semi-structured questionnaire, was carried out with 72 practitioners of traditional medicine. A total of 141 species belonging to 57 families have been identified. The most represented families were Fabaceae (12 species), Euphorbiaceae (09 species), Asteraceae and Poaceae (08 species each). The most cited species were : <i>Citrus aurantifolia</i> (Christm. &amp; Panzer) Swingle (7.23%), <i>Newbouldia laevis</i> Seem, (4.22%) and <i>Momordica charantia</i> L. (3.61%). 290 recipes have been inventoried and are used in the treatment of various diseases, the first of which is malaria (8.92%) followed by dysentery (6.69%) and overwork (5.58%). The decoction (35.86%) and the powder (23.68%) are the main methods of preparation of the recipes which are administered mainly by the oral route (65.34%) and by the cutaneous route (23.93%). The leaves (54.04%) and roots (16.47%) are the most used organs. Most of the organs are collected in riparian vegetation at the PNTS (29.73%), in the gardens (23%) and in the PNTS (20.58%). This study provides a database on plants with nutritional and therapeutic potential in Sédomé. Future pharmacological studies are planned on these recipes.</p>	<p>Ouro-Djeri, Hafez Koudouvo, Koffi Tchacondo, Tchadjobo Ouro-Djeri, Essowê Ohouko, Okri Fréjus Hans Gbeassor, Messanvi</p>

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### **Optimization and development of outdoor saprophytic mushroom cultivation via a network of regional producers**

Nearly 100,000 tons of cultivated mushrooms are produced in Canada each year, not to mention the wild mushrooms that are harvested from the forest. Despite this, Canadian companies still struggle to supply the market, while current Quebec production covers a mere fraction of total consumption in the province. Although stakeholders in Kamouraska, Quebec have been investing in the development of a mycoeconomy since 2009 with demonstrated results, focus must be placed on efficient mushroom production methods using established vegetation cover in order to diversify forest producers' sources of income and strengthen local supply. The Groupement forestier Grand-Portage and Biopterre took the initiative to evaluate different production techniques for saprophytic mushrooms, selecting the wine cap stropharia and shiitake, in order to increase potential yield. This was done with the help of a research network of 20 regional mushroom producers, approximately 200 experimental plots for wine cap stropharia, and shiitake fruiting blocks using three different strains. With regard to the shiitake, solid inoculation performed better than liquid inoculation in a controlled environment for two of the three ligneus species. Results demonstrated, among other things, that wood chip substrate was more productive than straw substrate, and that planting before the beginning of July resulted in a higher production potential for the wine cap stropharia. These observations were explained by characteristics such as substrate C/N ratio, porosity, and susceptibility to contamination and pests. Other challenges related to controlling fluctuations in production resulting from a number of factors in the outdoor environment will need to be addressed.

Perron, Béatrice  
Primeau-Bureau, Félix  
Malenfant, Pascale  
Hénault-Tessier, Maryse  
Tardif, Maxim

## F. Transitioning to a Viable Economy

### **Building Geographical Indication in vanilla production in agroforestry in Guadeloupe islands: a tool for rural development and agrobiodiversity conservation**

In the past, vanilla was a traditionally crop in Guadeloupe (10 tonnes produced in 1939), but the development of the two mains monocropping systems for the export market, sugarcane and banana during the 1940s lead to the decline of vanilla production. The vanilla production is currently in a revival dynamic driven locally by leading producers (Cédric Coutellier, winner of the gold medal at the general agriculture contest of Paris) who are actively involved in the agricultural and rural development of their territory. As coffee and cacao production, vanilla is cultivated in the undergrowth and the revival of these productions is very interesting because they can develop without competing, in terms of land, with existing crops since they grow under cover. Faced with competition from other countries whose cost competitiveness is unsurpassed, only an upgrading will make it possible to preserve or even increase the market shares of overseas producers of vanilla. The project therefore aims to promote quality vanilla with traditional know-how and to conserve biodiversity from agroforestry systems, by mobilizing a sign of quality and origin. 80 interviews were conducted with stakeholders in the vanilla sector with the aim of making an inventory of the vanilla sector in Guadeloupe. A complete inventory of cultivation, processing and marketing practices was carried out. Several studies showed that the ability for a GI to protect interesting biodiversity in agroforestry systems is highly dependent on the requirements defined for production. An analysis was undertaken in order to understand the organization of the sector and the succession of actions carried

Cassu, Marion  
Barraud, Emilie  
Coutellier, Cédric

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<p>out by the actors to produce, transform, sell and consume a product. A typology approach was developed on the base of data collected in order to study the diversity of the systems encountered and to characterize their main constraints for high quality vanilla production.</p>	
<p><b>A Value chain on Industrial Agroforestry - A Consortium approach for self-reliance in raw material security</b></p> <p>Industrial Agroforestry has gained significant attention and attraction due to its role in extending industrial raw material resources besides catering to the needs of eco system services. In India, the demand for wood products is increasing at an alarming rate due to industrialization, population explosion, urbanization, rural development, housing sector etc. It is estimated that the country's demand for wood for meeting the raw material requirement of organized wood based industries is over 152 m. m3. An equal quantity of wood is also demanded for meeting the raw material requirement of unorganized industries. The demand of energy both for domestic and industrial utility has been estimated to over 380 m. m3. This demand coupled with accelerated wood utilization in all sectors of development has ushered in a total mismatch between demand and supply. It is estimated that over 70% of this demand is met from agroforestry. However agroforestry in India has witnessed wide range of challenges like lack of improved genetic resources, quality planting material, multipartite supply chain, absence of price supportive system which detracts agroforestry promotion. To resolve these issues, FC &amp; RI, has developed a value chain model which resolved the issues identified in the entire Production to Consumption System (PCS) in agroforestry. The development and deployment of HYSR clones, mini-clonal technology, implementation of contract farming, and extending price supportive system through a consortium approach are the major innovations introduced and implemented. The improved genetic resources augmented the productivity to over 25 m3 / ha / yr and ensures profitability to famers. This value chain system has made a significant impact in Industrial Agroforestry development and created over 80,000 ha area in 10 years and sustainability in raw material security. It has created 2.4 million man days of employment and sequestered 4 million ton of Carbon thereby safeguards social and environmental issues.</p>	<p>Kallappan Thangamuthu, Parthiban Cruzmuthu, Cinthia Fernandaz</p>
<p><b>Bioeconomy and agroforestry</b></p> <p>Agroforestry has been already recognized as a sustainable land use system. The AGFORWARD project highlighted that around the 10 and 0.01% of the grasslands and arable lands are managed under the silvopasture and silvoarable agroforestry practices, respectively. Increasing the share of agroforestry in both agricultural and forest lands is crucial to reach the climate change, biodiversity and sustainability goals of the EU. Farm management technical knowledge of woody perennials should be improved to provide the best options to combine both understory and overstory components maximinzing farmers' income. The AF woody component management and use is seen as a main concern by farmers to adopt AF. The high cost of the woody perennials establishment and maintenance, the reduction of the farm area to deliver agricultural products, and the lack of market for the woody perennial products. Woody perennials use should be seen as an opportunity by farmers to develop bioeconomy across Europe. The delivery of products from the woody perennials is a major challenge that has to take into account both the development of alternative products (e.g. biochar, fuelwood, high value products (e.j. cosmetic compounds...)) and their respective value chain through the enhancement of farmers cooperation and adequate business environment provided by the administration. Bioeconomy is seen as an opportunity also from a society point of view, as the development of biofertilizers such as biochar from woody perennials can reduce the GHG emissions linked to</p>	<p>Mosquera-Losada, Maria Freijanes, Josejavier Francisco Javier, Rodriguez-Rigueiro Alvarez-Lopez, Vanessa Nuria, Ferreiro-Domínguez</p>

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<p>the transport and creation of mineral fertilizers, the replacement of fossil fuels by renewable energy and the delivery of new products replacing syntetic products coming from petrol (cosmetic, textile...). Agroforestry represents a huge benefit for both farmers and society.</p>	
<p><b>Incorporation of <i>Myrica esculenta</i> in agroforestry model for the upliftment of rural livelihood in Uttarakhand, India</b></p> <p>Non timber forest products (NTFPs) are known as a very important income-generating and ecologically sustainable resource throughout the world. Among NTFPs in the Himalayas, wild edibles have shown a huge potential and <i>Myrica esculenta</i> Buch.-Ham.ex D. Don (Myricaceae) locally known as Kaphal in Uttarakhand, India is one such promising species. The wild edible fruit trees of the Himalayan region have one of the richest sources of various antioxidant bioactive compounds and activity. <i>Myrica esculenta</i> has great prospect of being an agroforestry woody component as the tree has immense medicinal, economic and ecological uses. It is widely recognized among local people for its delicious fruits and processed products. This tree has the capability to fix atmospheric nitrogen enhancing its scope in agroforestry models especially in wasteland or degraded areas. The intercrop such as ginger, turmeric that grows well in Himalayan terrain can be successfully incorporated with <i>M. esculenta</i> as an agroforestry model. The study was carried out in Mussoorie Forest Division, Uttarakhand, India. A total of 9 villages were surveyed during 2019 - 2020. It was found that the local inhabitants collect fruits from the forests and sell them on the road side thus gaining seasonal employment at the time of fruiting in the month of April-May (summer season). <i>Myrica</i> fruit contributed an additional income of over Rs. 3,50,000/season to the economy of the villagers. Income generation can be improved by introduction of value addition and additional processing of the final products. Therefore, <i>M. esculenta</i> has huge prospects and can be incorporated in several agroforestry models securing both livelihood improvement and conservation of natural resources.</p>	<p>Chanu, Thounaojam Bidya Singh, Charan Bahar, Nawa</p>
<p><b>Agrobranche Project: Towards sustainable wood fillers from agroforestry for WPC</b></p> <p>Current environmental concerns push towards more sustainable and local practices for biomass production. In this regard, agroforestry has been highlighted by researchers and policies as a highly efficient approach for carbon sequestration, and a sustainable alternative to short coppice rotation. One of the key parameters for agroforestry adoption is of course the short-terms return. Agroforestry implies regular branch cuts that are processed into wood chips and mostly used as energy wood. New higher added-value chains could be considered such as reinforcements or specific molecules for bio-based materials and chemistry. Since 90's, Wood-Plastic Composites (WPCs) have experienced significant growth, particularly in building, and constitute the largest share of bio-based composites developed at an industrial scale. Nevertheless, the quality of WPCs and variability in their performance are major technological issues for their implementation in industrial applications. This could be related to the difficulty in tracing the various origin of wood fillers as well as the different processing steps, from wood drying and defibration process to composite manufacturing. In this context, the development of quality-controlled agroforestry wood fillers in terms of granulometry, chemical composition and physical properties is therefore strategic for their implementation in wood-based products. This work investigates and evidences the influence of wood species (poplar, oak, walnut, chestnut)) and filler size and shape on the microstructure and mechanical properties of polypropylene (PP) / wood composites manufactured by extrusion/injection moulded. Moreover, wood from three recovery platforms in Brittany (mix of several species) was also investigated</p>	<p>Liagre, Fabien Le Moigne, Nicolas</p>



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<p>to evaluate the potential of existing agroforestry feedstocks. A definition of wood species and fractionation routes have been produced to optimize composite performances in relation with wood structure (anatomy, cell wall composition). From an economical aspect, the agroforestry chips are perhaps less interesting than the forestry chips, but with a better Life Cycle Analysis and strong impact on the agriculture environmental services.</p>	
<p><b>Mitigation and Adaptation Potential of Eucalyptus and Poplar based Agroforestry in Northern Plains of India</b></p> <p>Agroforestry and Trees Outside Forests (ToF) potential as Mitigation and Adaptation Potential needs to be given due recognition and impetus in meeting Land Degradation Neutrality (LDN) Targets, Bonn Challenge Commitments and Restoration initiatives. The Study analyzes the potential of adoption of Agroforestry Practices as Mitigation option in Northern Plains (occupy 9 % of Total Geographical area of India, having net sown area of 71.45%) one of the 14 physiographic zones as per Forest Survey of India(FSI) Classification. Northern Plains agroforestry are mainly based on short rotation tree species of Eucalyptus spp.(Eucalyptus tereticornis) and Populus spp.( Populus Deltoides) in combination with or without agricultural crops. Eucalyptus and Poplar have been adopted as tree species in combination with agricultural crops, due to short rotation, linked market supply chains, value additions, supplementing economic returns and green livelihoods. Present status of Eucalyptus and Poplar based agroforestry in Northern Plains as proportion of Net Sown Area has been estimated. Mitigation Potential under hypothetical scenarios of 1%,2.5 %,5%,7.5% and 10 % of Net Sown Area (NSA) and incremental Carbo Value has been estimated. The study concludes that mitigation and adaptation potential of selected agroforestry models exists in Northern Plains. Increase in area under agroforestry also provides an opportunity to access Carbon Markets , with enhanced net income to farmers in addition to National and Global Environmental objectives under Bonn Challenge, Forest Restoration and mitigation of Carbon emissions. However, the proportion or level upto which agroforestry can be adopted as per various hypothetical scenarios depends on better economic returns, adequate pricing, market availability, policy reforms, mitigation and ecological benefits without compromising the food grain production requirements.</p>	<p>Saxena, Vivek</p>
<h3>G. Transitioning to a Viable Society</h3>	
<p><b>Transforming university agroforestry education to continue during COVID lockdowns in Indonesia: opportunities and challenges</b></p> <p>Background: Indonesian government regulations on ‘nomenclature’ have prevented establishment of agroforestry as a formally recognized education stream, even though policy recognition for agroforestry and associated job opportunities are increasing. The Indonesian government implemented lockdown policies to reduce the spread of the COVID19 virus early in 2020, forcing universities and other educational institutions to shift to ‘on-line’ modes of education. Through a ‘Free Campus’ program, the government also stimulated ‘virtual exchange’ between universities, leading to student groups with more diverse background knowledge and experience. This condition required lecturers to be more creative and more skilled in preparing teaching materials by utilizing existing software and gadget technology, adjusted to the heterogeneous internet access available to students in their home areas. Objectives: Development of multidisciplinary agroforestry teaching material that can guide students from</p>	<p>Hairiah, Kurniatun Suprayogo, Didik Kurniawan, Syahrul</p>

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<p>various university backgrounds throughout Indonesia to independently grasp Agroforestry in terms of cognition, skills and motivation-attitudes, with reduced interaction with teachers and groupwork in practicals. Methods: Twelve agroforestry modules (<a href="https://online.flipbuilder.com/bcuky/dvyh/">https://online.flipbuilder.com/bcuky/dvyh/</a>; in Bahasa Indonesia), each clarified learning goals, providing a video-taped lecture, and suggested practicals, using audiovisual materials freely available on-line. Results: Initial response by students to the replacement of classical 'lectures' by discussion-based tutorials, expecting students to study the subject matter beforehand from on-line resources, including video-taped lectures, was positive, with student-led discussions of selected publications allowing for the diversity in backgrounds and levels of understanding. However, over time the lack of real-life contact for the students and motivational opportunities of group-based activities became noticeable. Discussion and conclusion: In pre-covid education every lecture interpreted the curriculum differently and used her/his own teaching style. The streamlined materials brought more consistency and challenged lecturers to use two-way interaction in the virtual face-to-face sessions. While the cognitive objectives can be met, the skills and motivation-attitude aspects remain harder to monitor and achieve.</p>	
<p><b>Livelihoods, gender and climate change in the eastern Himalayas</b> The Hindukush Himalayan region encompasses a large area covering many countries in the North, South, and Central parts of Asia. People living in these mountains face huge complexities arising from several factors including terrain characteristics, micro-climates, environmental degradation, access to basic services, etc. These complexities vary as one moves geographically from one region to the other. The State of Sikkim in the North-Eastern part of India also observes similar challenges. Exposure to extreme events is location specific and communities settled in high, mid, and low altitudinal regions are differentially affected. Climate change impacts are disproportionate and influence lives and livelihoods variedly. One crucial determinant of these disproportionate impacts is gender – existing social norms determine roles and responsibilities, entitlements, and capabilities, thereby influencing the individual perceptions of shocks and susceptibility which vary across gender groups. The paper seeks to draw insights from the various field studies conducted in these locations to understand the gender vulnerabilities that manifest through a combination of complex and interlinked factors. It seeks to understand the existing social practices typically associated with these gender groups and how changes in the climate are and potentially influence vulnerability. The study makes use of qualitative research methods to understand gender roles, responsibilities. The study tries to bridge a crucial gap in research – of providing empirical evidence on gender mediated vulnerability in an under-researched climatic hotspot – the Hindu Kush Himalayan region. The study reiterates the role of place-based vulnerability in influencing lives and livelihoods and emphasizes the lack of access to human, financial, and natural capital as predominantly driving gendered vulnerabilities.</p>	<p>Sharma, Ghanashyam</p>
<p><b>Gender and Ethnicity in Vietnam Agroforestry Landscapes: Lessons for Project Implementation</b> The ethnic groups living in the mountainous areas of Vietnam have unique social, cultural norms and values in relation to gender, which influence their adoption of agricultural interventions. We used gender-responsive participatory methods to explore their gender norms and relations, information and knowledge sharing systems, together with their challenges and opportunities for sustainable agricultural development. Two case studies have been conducted with Thai and H'mong communities who participated in agroforestry landscapes to compare their gender norms, opportunities and challenges in agroforestry adoptions. The</p>	<p>Nguyen, Mai Phuong</p>



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<p>findings show that agricultural activities are highly gendered. Men and women played specific roles and have different, particular constraints and interests. Women were highly constrained by gender norms, access to resources, decision-making power and a prevailing positive-feedback loop of time poverty, especially in the Hmong community. A holistic, time- saving approach to addressing women's daily activities could reduce the effects of time poverty and increase project participation. As women were highly willing to share project information, the project's impacts would be more successful with increased participation by women through utilizing informal channels of communication and knowledge dissemination. Extension material designed for ethnic women should have less text and more visuals. Access to information is a critical constraint that perpetuates the norm that men are decision-makers, thereby, enhancing their perceived ownership, whereas women have limited access to information and so leave final decisions to men, especially in Hmong families. Older Hmong women have a Vietnamese language barrier, which further prevents them from accessing the project's material. Further research into an adaptive framework that can be applied in a variety of contexts is recommended. This framework should prioritize time-saving activities for women. Lastly, the study provides recommendations for agricultural projects and extension staff to become more gender responsive.</p>	
<p><b>Documenting agroforestry use at the country level: a United States perspective</b> While agroforestry benefits are well-documented in the research literature, much less is known about actual agroforestry implementation within countries. Having a greater understanding of how prevalent agroforestry is across a nation is important for: 1) understanding trends in agroforestry implementation, 2) helping producers make more informed decisions, 3) identifying market opportunities, 4) matching support with producer demand, and 5) informing decisions related to policies, funding, programs, research, and delivery. To address these issues, the U.S. Department of Agriculture National Agroforestry Center (USDA NAC) evaluated data regarding agroforestry use in the United States. To date, the best available data at the national level is the 2017 USDA Census of Agriculture where producers in the U.S. were asked if they practiced at least one of the five common agroforestry practices (alley cropping, silvopasture, windbreaks, riparian forest buffers, or forest farming). Over 30,000 farm operations responded yes to this question, representing 1.5% of all farming operations in the U.S. Some of the states with the highest percentage of operations practicing agroforestry were Vermont (7%), Hawaii (5%), Oregon (4%), and Pennsylvania (3%). In addition to state-wide summaries, data is available at the county level, which provides a finer level spatial assessment across individual states. Building off this survey sample, USDA NAC has developed a comprehensive follow up survey that will be sent to farms identified in the 2017 Census of Agriculture as using agroforestry. Questions in this survey will investigate acreage, establishment methods, management practices, benefits and challenges, and products sold for each agroforestry practice. This survey will be launched in 2022 and is a USDA interagency collaboration involving the Forest Service, National Agricultural Statistics Service, Natural Resources Conservation Service and Agricultural Research Service. Lessons learned on assessing agroforestry implementation will be discussed.</p>	<p>Bentrup, Gary Smith, Matthew Macfarland, Kate Kellerman, Todd Ameyaw, Lord Straight, Richard</p>
<p><b>Developing tree-based value chains to accelerate restoration project in Africa: case of shea butter value chain development</b> Background: Tree based value chains development in Africa have received limited recognition considering challenges of negative resources over-extraction such as with charcoal and long investment periods needed. Efforts to scale tree-based restoration therefore suffer inherent set backs on availing meaningful market incentives to drive local participation in restoration efforts. Meanwhile,</p>	<p>Carsan, Sammy Arinloye, Djalal Wamuongo, Davis Koech, Grace Bourne, Mieke</p>

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<p>degradation of parklands systems, lack of regeneration, poor harvesting techniques, fire, lack of tree and land tenure are impeding business development. We focus on the case of shea butter value chains to illustrate this situation. Objectives: To assess opportunities and constraints on tree enterprise development covered by The Regreening Africa project. Methods: Cross country learning events, focused group discussions, project site visits have been used to appraise value chain development status. Results: Findings have provided crucial lessons and experiences on shea butter resources management, marketing, women involvement, actor participation at local and international scale. Discussions: Stimulating development of local tree enterprises that could grow interest and investment in well-known products such as shea with primary value chain activities supported by women provides crucial linkages to improve domestic and international markets horizons for products such as shea butter. Conclusion: Opportunities exists for building success, dealing with bottlenecks, unlocking local finance, leveraging local partnerships and developing improved germplasm input systems that guarantees future productivity and sustainability for tree based enterprises such as shea.</p>	
<p><b>Typology and dynamics of agroforestry systems in the mountains of Timor Leste</b> In Timor-Leste, a country located in the south-east of the Indonesian archipelago, GIZ has initiated a project with the aim of developing agroforestry systems (AFS) that are productive, profitable and preserve natural resources. Since 2020, CIRAD researchers have joined the project wishing to describe the diversity of traditional AFS existing in the country. In the Baucau region, located in the north-east of the country, at altitudes 0-1500 m, with rainfall 1000-2000 mm/year, first inventories and surveys have identified 5 types of AFS which vary greatly in function of their tree density. From the lowest to the highest tree density system: i) Crop system including a Fallow phase (3 months to 10 years) (CF), ii) SylvoPastoral system (SP); iii) Young Agroforest (YA); iv) Home Garden (HG); v) Forest Garden (FG). Further biomass inventories, soil observations and sampling, participative mapping activities along with Peeble Score Methods and semi-structured interviews contributed to characterize the AFS at a socio-economic, ecological and agricultural practices level. The AFS evolution hypothesis is that they become denser over time, with an increase in biodiversity. However, it has been observed that home and forest gardens are often managed by older people for varied but self-consumed crops, whereas young people are looking for crops that are more marketable and easier to cultivate in non-agroforestry systems. In order to avoid the clearing of these AFS, it is necessary to look for methods to intensify production, adapt it to the needs of young people and valorise the products. Finally, AFS are also markers of the complex social order between families in the same village or with other villages: concerning the sharing of tasks, ownership and exploitation of land products. It is essential to take these factors into account if continued external support is to be provided.</p>	<p>Cogne, Marguerite Peltier, Régis</p>
<p><b>Culturally-linked ecosystem and agroforestry management education for island communities</b> The Hawaiian Islands are famous for both an outsized number of endemic species and an outsized extinction rate. Worldwide, the highly isolated islands were one of the last landmasses to be colonized by humans. Native species suitable for human sustenance are rare; since the arrival of the first Polynesian voyagers, food produced in the islands has been almost exclusively introduced species. Traditional Hawaiian agriculture utilized trees and herbaceous crops but the rate of introduction of new species and the establishment of invasive species increased exponentially after the arrival of the first Europeans and the establishment of plantation agriculture. In Hawaii, production of food and preservation of natural</p>	<p>Scheffler, Pamela Steele, Orlo</p>

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<p>ecosystems have been largely at odds and treated as separate issues. The Forest TEAM (Tropical Forest Ecosystem and Agroforestry Management) Program at Hawaii Community College was established in 2002 to address the need for a local workforce that understands both ecosystem management and food production techniques. Students chose from a 2-year degree (A.S.) or 1-year certificate (C.A.) and, upon completion, have the option of transferring to 4-year programs. TEAM is unique in introducing traditionally under-represented students to the fields of agroforestry and ecosystem management. Students learn in a hands-on interactive environment where lectures, fieldwork and visits to local projects, teach science, agriculture and traditional cultural knowledge. The Program has awarded 139 degrees to graduates, 50% who identify as indigenous or mixed-indigenous (Hawaiian, American, or Alaskan Native) and 71% who are from a minority ethnicity. These graduates provide the workforce with culturally-connected individuals who support the local agriculture and economy while preserving unique Hawaiian ecosystems. The model of providing culturally-relevant, science-based education to island communities that empowers local residents to address issues important to ecosystem preservation and human well-being, is useful for future education on impacted islands.</p>	
<p><b>Citizen science and serious games as complementary steps to landscape governance involving trees and agroforestry</b>  Background: Two complementary trends in the natural resource management and landscape governance domains e.g. citizen science and serious games, have similar goals, but different starting points. Both aim for a strengthening of shared understanding of conditions and trends, greater roles for local stakeholders in decision-making and the emergence of innovative, 'out-of-the-box' solutions, not constrained by current rules and land use concepts, supported by concepts such as 'co-production of knowledge' and 'co-management'. Yet, the citizen science and serious game communities of practice have developed separately, with different geographical foci. Objectives: Identifying opportunities for greater complementarity and synergy between 'serious games' and 'citizen science' as different ways of linking specific, place-based pattern information to generic, process-based concepts, in support of locally desirable system change. Methods: Review of literature and practitioners insights on the challenges both games and citizen science have in quantifying and analysing outcomes and impacts in terms of individual cognition and skills, constraints to collective action and power to push 'policy issue cycles' forwards. Results: We will present results based on: i) historical background, ii) differences and similarities between the two approaches, iii) the current application fields, iv) and the potential synergy between citizen science and serious games. Discussion and conclusions: The two 'communities of practice' may need some further opportunities to develop complementarity and synergy in specific contexts, as steps in a joint learning process.</p>	<p>Speelman, Erika N.  Becu, Nicolas  Marcos, Diego  Van Noordwijk, Meine</p>
<p><b>A survey of measurement and evaluation tools for urban forest gardens: impact of the Rahma Edible Food Forest Garden in Syracuse, NY</b>  The Rahma Edible Food Forest Snack Garden is an urban agroforestry landscape located on 1/5th-acre of private land on the Southside of Syracuse, NY. The current 10 year old Rahma landscape was developed from an empty lot with few pre-existing species other than grasses and two serviceberry trees (<i>Amelanchier</i> sp.). Parts of the original funding for project expenses were obtained in the form of a \$5,000 grant from the Onondaga Lake PArtnership in recognition of the site's potential to provide ecosystem services including the slow down of rainwater infiltration into the city's combined sewer overflow system. In 2019, a preliminary environmental benefits assessment was conducted using the modeling programs i-Tree Hydro, i-Tree MyTree and i-Tree Design - a suite of free computer programs</p>	<p>Cetera, Frank  Coville, Robbie</p>

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<p>from the US Forest Service that simulate the physical processes and relationships of the ecosystem on site. Continued research is currently being conducted to identify other assessment tools that can quantify additional benefits of the site beyond the ecological such as social, economic, and health components. The tools selected will be tested on the Rahma Edible Forest Snack garden and the impact benefits summarized. The selected tools will be collated into a toolkit geared towards urban agroforestry projects that will allow citizen scientists and community stewards to measure benefits across a holistic range of socio-economic factors. The results of the Rahma case study data will be included in the toolkit to demonstrate the use of the selected tools. Such measurements can be used to lobby decision-makers and stakeholders at both community and governmental levels for the provision of funding and support to increase urban agroforestry landscape implementation towards transitioning to a more viable society.</p>	
<p><b>Growing together: How networks support women's access to land for perennial agriculture in the Midwest</b></p> <p>Secure land tenure is a requirement of agroforestry but in the US accessing land is getting harder and harder for young farmers, particularly women who don't come from a farming family and don't have prospects for inheriting land. Research shows that women farmers find great support in networks and agricultural organizations, particularly those specifically geared towards women so, with this research, I sought to better understand how these networks support them in the process of accessing land for perennial agriculture and agroforestry. I conducted interviews with 12 women from three Midwestern states and asked them to share with me their stories of land access and the role that networks played in the process. The use of open-ended interviews and free-floating prompts allowed these farmers to tell their stories in their own words and helped uncover common themes that were used to analyze the data collected. They explained that networks helped them access land and build their perennial farming projects by (1) facilitating their access to land, (2) sharing of knowledge and resources, and (3) offering support as women in a men dominated industry. Throughout these conversations, two narratives emerged: "pay it forward" and "farm collaboratively." I argue that these narratives can help organizations better support women looking for land to implement agroforestry practices. They also highlighted the importance of encouraging just approaches to farming that participate in opposing the systems of oppressions that have limited access to land and perennial agriculture. Additionally, these conversations shed light on the need for organizations to promote and facilitate collaborative land access approaches. In conclusion, this research highlights the importance of networks in women's success in accessing land for perennial agriculture and offers pathways for facilitating the adoption of agroforestry through the promotion of collaborative and just land access approaches.</p>	<p>Decre, Barbara</p>
<p><b>Verdissement social des espaces urbains: plein feu sur les jardins Gamelin</b></p> <p>Pour une septième année consécutive, de début juin à fin septembre, la Place Émilie Gamelin a été entièrement réaménagée en une grande terrasse publique structurée par des bacs d'agriculture urbaine, des arbres, des jardins thématiques et une serre. Ce projet de verdissement social est réalisé en collaboration avec le Partenariat du Quartier des Spectacles et Sentier Urbain. En tant que chargée de projet qui coordonne les jardins, je voudrais réaliser une présentation sur les bienfaits du verdissement social sur le territoire et la collectivité pour une transition verte et inclusive. Depuis ses débuts, une des missions premières des jardins Gamelin est de produire des aliments comestibles pour nourrir celles et ceux qui habitent le parc, en plus de combattre les îlots de chaleur et proposer un</p>	<p>Stien, Gabriella</p>

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<p>espace vert ouvert à la collectivité dans son ensemble. Également, le jardin poursuit la mission d'éduquer et de sensibiliser le grand public sur les vertus et bienfaits du verdissement et de l'agriculture en ville par le biais d'ateliers, de conférences et de visites guidées. Notre équipe travaille notamment avec des organismes locaux d'aide à l'itinérance pour mobiliser les usagers du parc et collabore étroitement avec plusieurs organismes de réinsertion socioprofessionnelle, ce qui permet à des jeunes au parcours atypique de pouvoir gagner de l'expérience en horticulture et en agriculture urbaine.</p>	
<h3>H. Transitioning to a Viable Development</h3>	
<p><b>Sustainability assessment of agroforestry farms in and around the Luki Biosphere Reserve in Central Kongo, Democratic Republic of Congo</b></p> <p>Context. The IDEA method (Indicateurs de Durabilité des Exploitations Agricoles) or Farm Sustainability Indicators (FSI) method has been used since 1998 to assess the sustainability of agricultural farms. Objective. This method was adapted and used for the first time to study the sustainability of agroforestry farms located in and around the Luki Biosphere Reserve (LBR) in the Democratic Republic of Congo (DRC). Methods. The method is based on 41 sustainability indicators covering the three scales of sustainability (economic, agroecological and socio-territorial dimensions). It was applied on a sample of 58 agroforestry farms (29 model farms and 29 traditional farms). The data of the 41 sustainability indicators of the three sustainability scales were collected in the form of a survey questionnaire. A principal component analysis (PCA) was conducted to analyze and group the agroforestry farms and assess the scores of each scale of sustainability. Results and discussion. The results showed that the surveyed farms presented good scores on the agroecological sustainability scale, near to 50.0/100 for traditional farms (TF) and near to 60.0/100 for model farms (MF). The scores of socio-territorial and economic scales were very low. The PCA helped characterize each sustainability scale for the agroforestry farms and allowed to clearly separate the two groups of agroforestry farms (traditional vs model) on the first two factorial axes. Based on the first factorial axes of the PCA, which alone explains 55 % of the total variance, the results showed that all the model farms surveyed had higher sustainability scores based on their ranking than the traditional farms. Conclusion. We suggest that the FSI method developed since the late 1990 years to assess the sustainability of agricultural farms can be modified and applied for agroforestry farms.</p>	<p>Khasa, Damase</p>
<p><b>Innovation, bioeconomy and agroforestry</b></p> <p>The 1500 AF actors in the AFINET project identified the main agroforestry challenges to be overcome to foster AF in Europe. Within those, the technical knowledge development and exchange, the economic benchmarking, as well as the farmers and consumers education as well as adequate policies are considered crucial. The economic challenge should be focused on two relevant topics: (i) the economic evaluation of AF alternative land use compared with treeless systems in both organic and conventional farming systems but also (ii) the woody component bioeconomy development through the analysis of alternative and new woody perennial (trees or shrubs) products and use such as heating, fibers, fodder etc, new markets, new infrastructures through the business plan analysis... The educational challenge have to evaluate the provision of innovative methodologies that will make consumers willing to pay for more sustainable products (i.e. AF labelling), by the identification of already existing networks (operational groups),</p>	<p>Mosquera, Maria Santiago-Freijanes, Josejavier Rodríguez-Rigueiro, Francisco Javier Alvarez-Lopez, Vanessa Tamara, Franco Grandas Ferreiro-Dominguez, Nuria</p>



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<p>the promotion of advisory challenges (extension services) and the provision of tools to facilitate the advisory systems. Projects like AE4EU, EURAKNOS or EUREKA highlight the needs of adequate advisory services, networking and education. Policy should consider the policy analysis carried out within the AGFORWARD and AFINET projects associated with the previous AF policy concerns, current AF promotion and adoption to develop innovations for policy makers under the new CAP strategic plans developed at national level. The compilation of previous innovations (AFINET, AGFORWARD, AE4EU and AGROMIX) fulfilling the aforementioned four challenges (technical, economic, educational and policy) will be the basis to understand the challenges, developing the outputs with regard to biodiversity, climate goals and ES. The business environment that aims at understanding the institutional development, funding, market structure, consumer agency, technology &amp; knowledge, resources and infrastructure and training &amp; education arenas are key to foster strategic AF business models.</p>	
<p><b>Nursery Supply Chains and Agroforestry in the United States</b> Federal, state, and corporate initiatives promoting large-scale reforestation and afforestation efforts on public and private lands have gained momentum and support from scientists, policymakers, and practitioners. Notably, there is growing awareness of the potential of agroforestry to address carbon mitigation goals, diversify incomes, safeguard water quality, enhance ecological resilience, and numerous other transdisciplinary outcomes. However, a nursery supply gap undermines the feasibility of widespread tree planting in the United States. In recent decades, the number of nurseries and seed storage and processing facilities in the country have decreased. Causes for declines in seedling production vary regionally and include market forces as well as cuts in federal and state cost-sharing programs that support the Conservation Reserve Program and state-run nurseries. Although capacity for tree production varies, most regions lack the current seedling supplies and infrastructure necessary to meet the growing reforestation demand. Research is needed to assess the disconnect between a shrinking and fragmented nursery supply chain and the rise of interest in tree planting, specifically agroforestry. In particular, understanding and elevating nursery suppliers' perspectives about their priorities and perceived opportunities and limitations is urgently needed. This information will help build a robust nursery supply chain that addresses both suppliers' goals and the growing demand for trees catalyzed by reforestation initiatives while maximizing social, economic, and ecological co-benefits. In this presentation, we will share our findings from semi-structured interviews with nursery owners in the United States, with perspectives from both rural and urban producers. We will present current successes and challenges in the sector and highlight opportunities to support nursery capacity and growth to enable the adoption of agroforestry practices for a myriad of management goals. We will also discuss conclusions related to the importance of supporting local, place-based efforts to increase nursery capacity that will provide regionally-specific species and resources.</p>	<p>Colburn, Lily Guadagno, Luca Jovanelly, Kristen Repka, Marisa</p>
<p><b>Improving living conditions of rural families through diversified agroforestry systems in Honduras</b> Honduras is one of the poorest countries of Latin America; more than half of its inhabitants live in poverty, and this rate is even higher among rural areas. The inner country is mostly mountainous, and the coasts are set as narrow plains. Honduras is extremely susceptible to extreme weather including hurricanes, floods, and droughts. In 2017, SOCODEVI received funding from Global Affairs Canada to start the CAHOVA project whose objective is to improve the living conditions of poor women, men and youth affiliated with agricultural associative enterprises (AE) located in five rural departments of Honduras. This project was</p>	<p>Trudel, Richard Callaci-Trottier, Diego Lantagne, Serge Bélanger, Marie-Christine</p>

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<p>realized over a five-year period and ended in December 2021. It included the establishment of climate-smart agroforestry systems, improving the efficiency of AE processing processes and capacity, implementation of new technologies and innovations, and a massive capacity-building strategy, at two levels: households and the associative enterprise; on various topics including agroforestry production techniques, business management, and diversification of services. The presentation will focus on the climate-smart agroforestry systems implemented in the CAHOVA project, their species composition, areas implemented and potential return on investment. Along with that, an analysis of the livelihood conditions will be detailed. In 2017, 67% of the participating families were experimenting poverty, today this proportion has decreased to 53% of the participating families across all value-chains (cocoa, coffee, rambutan, pine resin, honey, wood processing). The CAHOVA project increased by 1,36 times, the profitability of smallholder farms. Also, the promotion of environmentally friendly agricultural practices such as using organic fertilizer or less toxic pesticides has improved the proportion of sustainable farms from 44% to 54%. SOCODEVI's integrated development method, combining capacity building at various levels and involvement of local actors such as associative enterprises, their members and families is the key to improving livelihood conditions in a sustainable way.</p>	
<p><b>Agroforestry-Focused Service Learning and Community Engagement in Cameroon's Mbalmayo Forest Reserve</b></p> <p>The Mbalmayo Forest Reserve (MFR) in Cameroon's Centre Region plays a critical role in regional water quality, wildlife, and farmer livelihoods, but degradative agriculture threatens its ecological integrity. The MFR also houses L'Ecole Nationale des Eaux et Forêt's (ENEF's) teaching, training, and research forest, which is an important regional agroforestry educational resource. Local communities who use the MFR for numerous resources opposed ENEF's recent efforts to rehabilitate their teaching forest and promote agroforestry practices in the MFR because they felt the process was too authoritative. ENEF and Virginia Tech University (VT) in Blacksburg, USA partnered in 2019 to study community member perspectives regarding ways to improve collaborative planning. Results indicated MFR community members are more interested in working with ENEF students compared to administrators or faculty, and that a sense of mentorship, service, and learning-based communication influences their perspectives. Working with students is viewed as a meaningful and less-authoritarian way to partner with ENEF to address MFR conservation using agroforestry. In response to these findings, ENEF and VT created a Research and Community Engagement (RESCOM) program based on the principles of agroforestry, service learning, and collaborative conservation. A RESCOM pilot is scheduled to occur in early 2022. The program trains ENEF students in agroforestry techniques, community engagement and outreach, and research and data collection. It also pairs students and community members to form assessment and research teams. After completing RESCOM, graduates are prepared to engage stakeholder communities when developing agroforestry management plans, conduct systematic qualitative and quantitative community-based research, and collect and analyze environmental data supporting projects such as REDD+. Community participants help identify mutually beneficial MFR and ENEF agroforestry projects, communicate and demonstrate needs to ENEF, and participate in natural resources research and problem-solving with long-term environmental and agroforestry workforce impacts.</p>	<p>Addlestone, Benjamin Munsell, John Kingsly, Neba</p>
<p><b>ROBUST: Agroforestry a sustainable agricultural system for plant and milk production in northern temperate climate</b></p>	<p>Rohde Birk, Julie</p>



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<p>Background: Agroforestry was practically non-existent in Denmark until 2017. From 2018-2020 three small pilot projects tried to map agroforestry effects on agricultural challenges in Denmark. It became clear that results from other countries could not be translated directly onto a Danish context and that we need research into these effects. Thus, began project ROBUST in 2020. The choice of focus on plant breeding and milk production is based on areas where there is the greatest potential for the spread of agroforestry in Denmark. Objectives: The aim is to research, develop and spread agroforestry in DK. The objective is to document the effect of agroforestry on important green parameters such as: carbon storage in soil and wood mass, nitrogen leaching, nature value, competition with crops, feed value of deciduous biomass and animal welfare, and to model the effects of spreading agroforestry on a larger national scale and examine the production economic effects. Methods: Four new organic agroforestry farms have been developed and established, and the farmers will have their systems continuously monitored regarding the following parameters. Animal welfare. The project will investigate the impact of trees on cattle animal welfare during grazing in relation to shade, shelter, shelter, and skin care. Biodiversity. The project will provide data that will form the basis for important knowledge about the biodiversity effects of forestry in northern temperate climates in regard to insects on the soil surface and in the air. Carbon and nitrogen cycles. The purpose is to determine C storage and N uptake in agroforestry systems woody plants (above and below ground biomass), including the annual C accumulation and N balance. To quantify and document competition between trees and agricultural crops there will be 1. Repeated yield measurements in crops at two experimental sites at four different distances from the planting. 2. Study of light and nutrient competition between trees and crops at two experimental sites. 3. Business potential. To explore the business potential of agroforestry in company brands by: 1. Development of agroforestry product portfolio. 2. Analysis of needs and value creation among customers. 3. Development of marketing material for agroforestry products. 4. Development of digital cultivation tools. Results: The project began medio 2020 and the first trees are planted ultimo 2021. Results will be available on an ongoing basis from 2021. Discussion: Interest in agroforestry has increased greatly since the start of this research project. In just a few years, a large part of the farmers has learned about agroforestry - a hitherto almost unknown phenomenon in Denmark. The potential for spreading agroforestry to many of these farmers is based to some extent on the verification and quantification of effects that this project will provide.</p>	
<p><b>Vietnam towards sustainable coffee and pepper production: the V-Scope project</b> Context: The rapid expansion of coffee and pepper in the Central Highlands between the 80s and 2000s has secured Vietnam as the world largest producer of Robusta coffee and black pepper. These two crops support more than 1 million livelihoods in Vietnam. Yet, the region remains among the poorest. It is home to marginalized ethnic groups. Furthermore, intensive farming practices have resulted in critical environmental degradations, jeopardizing rejuvenation and the overall sustainability of coffee and pepper production. In this context, the Australian Centre for International Agricultural Research (ACIAR) commissioned a research team led by the World Agroforestry (ICRAF) to support the coffee and pepper sectors in the Central Highlands. Objective: aligning with priorities of the Vietnamese central government and agribusiness strategies of lead coffee and pepper companies, the V-Scope project aims to increase the sustainability of coffee and pepper farming systems and value chains. The project will more specifically address the following: Improved soil health and soil-borne pests and diseases control; Improved sustainable farming practices with higher resource use</p>	<p>Rigal, Clément Bienabe, Estelle Nguyen, Mai Phuong</p>

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<p>and economic efficiency; Improved local value chains and national public-private dialogue; Improved capacity to implement up-scaling strategies, ensure long-term adoption of sustainable farming systems accounting for climate change adaptation needs, especially for indigenous ethnic minorities and women, and operate at landscape level through multi-stakeholder partnerships. Method: Activities will take place in Dak Lak (Krong Nang district), Gia Lai (Dak Doa district) and Dak Nong (Dak Song district) Provinces. They will include working on demonstration plots and within farmer networks of partner coffee and pepper companies, to harness the potential to work with the private sector in driving changes and achieving impacts at scale.</p>	
<p><b>Opportunities and Constraints to Establishing and Scaling up Nut Production as a Viable Component of NY State Agriculture</b></p> <p>Temperate tree nuts, in particular hybrids of hazelnuts (<i>Corylus avellana</i> x <i>americana</i>) and chestnuts (<i>Castanea</i> spp.), are a niche but emerging agricultural crop in the Eastern United States. Tree nut production offers important potential benefits including climate resiliency, carbon sequestration in plant biomass, increased soil health, utilization of marginal land, economic revitalization of rural communities, and the ecologically sustainable production of nutrient dense foods and value-added products. This study reports on three surveys of New York (NY) state agricultural producers, Cornell Cooperative Extension (CCE) agricultural educators, and commercial-scale nut growers to identify opportunities and constraints to establishing and scaling up nut production as a viable component of the NY agricultural sector. My findings show that nut growers in NY are focusing production efforts on hybrid hazelnuts and hybrid chestnuts. All respondents are highly dedicated to producing nuts in the future. They deeply care about ecological and social issues in agriculture and see nut production as a way of addressing those. Nut growers are trying to center ecological and social goals tantamount to economic viability. CCE educators vastly underestimated ecological and sustainability motivations. As a result, CCE educators were ambivalent that nuts could be a viable crop. Producers in other agricultural sectors across the state were more open to the idea of nut growing on underutilized and marginal portions of their land. These growers also reported much higher confidence that nut growing would be viable in their region, especially when informed that other growers have already started planting these trees. Lack of information and knowledge of current nut growers were common themes amongst both CCE educators and multi-sectoral agricultural producers in NY state. These results will be used to better inform needed nut tree based agroforestry research and extension programs in NY state.</p>	<p>Bosco, Samantha</p>
<p><b>Graphs theory applied to agroforestry system design</b></p> <p>Designing agroforestry systems is a complex task due to the numerous elements and their multiple interactions. Co-design workshops are useful to overcome these difficulties by gathering people from different disciplines. But these workshops use tools that do not provide a standardised representation of agroforestry systems nor the provision of ecosystem services. Our objective is thus to develop a conceptual information framework based on graphs that allows modeling the agroforestry system and its ecosystem functions. In the first step, we infer a topological graph from the position of the physical objects representing system components: trees, crops, tree lines, and their spatial relationships (e.g. adjacency, inclusion...). We represent then the relationship between ecosystem structure and functioning as a graph. Applying graph technics such as subgraph research, we can estimate whether a specific system (graph) can support a specific ecosystem function (subgraph). This results in a new graph-based model to describe both the spatial and functional relationships between elements of agroforestry systems. It</p>	<p>Lemière, Laëtizia Jaeger, Marc Subsol, Gérard Gosme, Marie</p>

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<p>illustrates the different steps to apply this model to a simple agroforestry system:</p> <ol style="list-style-type: none"> <li>1. Create a system mock-up with physical objects</li> <li>2. Acquire the scene by a camera and identify physical objects</li> <li>3. Automatically extract the topological graph</li> <li>4. Perform subgraphs research to identify functions</li> <li>5. Visualize the scene with both realistic trees and schematic representations of ecosystem functions.</li> </ol> <p>In the future, this work will be combined with augmented reality to visualize the agroforestry system and the production of ecosystem services directly on the physical mock-up. Thus, our work will improve the efficiency of co-design workshop by (i) formalizing the knowledge on the relationship between structure and function in agroforestry systems and, by (ii) sharing this information with non-specialists in a visual way, while allowing intuitive interaction through the physical mock-up. Thus, the designed system answers farmer's needs better.</p>	
<p><b>Considering the land blending strategy to move beyond the land sparing-sharing debate: the contribution of theoretical modelling</b></p> <p>To preserve both biodiversity and agricultural production, two land management strategies have been proposed: land sparing (setting apart natural ecosystems while intensifying agriculture) and land sharing (based on agroecosystems that can support both food production and biodiversity conservation). While the scientific community has been debating which of these strategies is the best, a third solution emerged lately that is a hybrid of the two previous ones. The land sparing-sharing debate is mired in large part because of the influence of the study context which greatly influences its empirical resolution, providing little guidance for generalization. We addressed this challenge using a theoretical modeling approach that allows for better generalization through its ability modify the context. We were interested in the influence of factors specific to the study context on biodiversity and landscape productivity, and therefore on the effectiveness of different landscape management strategies. Our model was based on a controller-pest interaction to focus on ecosystem services important for food production. We implemented in our model factors specific to the study context, such as landscape composition, species parameters, ecosystem services, impact of pest on crops and the planning timescale. Our results confirmed the importance of accounting for study context factors when evaluating landscape management effectiveness. We applied our model to a landscape of cocoa agroforestry, pastures, and natural tropical forests to illustrate the diversity of optimal solutions for landscape management depending on the context, even when study context factors differ only slightly. In all, our results indicate that landscape context is of utmost importance for the best strategy to support both biodiversity and food production. Our modeling approach also showed that a mixed strategy, which we call "land blending strategy", might provide optimal outcomes for the trade-off between agricultural production and biodiversity while providing flexibility for change and uncertainty.</p>	<p>Oliveira-Xavier, Aymeric Gravel, Dominique Calmé, Sophie</p>
<h3>I. Transitioning to Viable Policies</h3>	
<p><b>Restoring the Landscape through Family Run Agroforestry: a Strategy to Address Deforestation? A Case Study from Mexico</b></p> <p>Forest Landscape Restoration has identified and recommended agroforestry practices as a key instrument to revert land degradation globally. With a pledge to restore 8.5 M hectares in the Bonn Challenge, Mexico began in 2018 the operation of a National Restoration Initiative aiming to restore 1.2 million hectares by granting ~250 USD monthly to 450 000 marginalized families to support them in</p>	<p>Gonzalez Moctezuma, Pablo Rhemtulla, Jeanine Marie</p>

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<p>the establishment of 2.5 hectares of agroforestry plots on their own degraded lands. Many recent publications in the scientific literature have identified priority regions for restoration; in this study we ask to what extent the areas being restored by the Initiative correspond to those identified as of high restoration priority or as degraded by the literature. We overlaid municipality-level maps of beneficiaries enrolled in the Initiative (normalized by total population) with the restoration prioritization areas of Tobon et al. (2017) and with the forest cover loss of Hansen et al. (2013) and compared the allocation of resources to the Initiative with those suggested by Tobon and implied by Hansen. We found that several Natural Protected Areas that were not considered as needing restoration by Tobon were highly prioritized by the Initiative, and that some regions with strong Initiative coverage have accelerated forest cover loss since its establishment. We discuss the factors that the Mexican government appears to be prioritizing in its implementation of the National Restoration Initiative and compare these to the factors being prioritized in global restoration planning approaches. Although agroforestry has proven to be a powerful restoration tool, it is complex to understand how state-driven initiatives can motivate people to restore areas of high restoration potential while improving their livelihoods and complying with predetermined goals.</p>	
<p><b>Organic Farming of Sikkim state of India as a Strategy for Sustaining Ecosystem Services and Livelihoods: Lessons from the Eastern Himalayas</b></p> <p>The organic agriculture movement in Sikkim started in 2003 with a vision of sustainable livelihoods, conservation of the environment, and healthy food for all. The Sikkim Organic Mission was established in 2010 and the State Policy on Organic Farming was put in place in 2014. Today, Sikkim has emerged as a leader in organic farming in India and among the mountainous regions of the world. The organic movement in Sikkim has since matured to embrace various aspects of sustainable farming, production, and consumption of nutritious food, value addition, value chain development, marketing, social and business enterprise, and niche product development. Sikkim is a model Indian Himalayan state, which has made amazing progress in adopting environmental security in development plans and programs. In the past 25 years, Sikkim has achieved many milestones like making the State fully organic. The strategy clearly describes the vision, mission, and strategic goals for organic farming and entrepreneurship development in Sikkim. Global standards and principles of organic farming are considered in the strategy as they fit well with traditional farming practices in the state and meet the organic farming aspirations of Sikkim. The brief descriptions of the State Policy on Organic Farming, Sikkim Organic Mission, and legislations on organic farming provide the context and policy framework for the strategy. In 2018, the National Institute for Transforming India (NITI Aayog) released a set of reports on “Sustainable Development in the Himalayan regions”. Sikkim developed its State Action Plan on Climate Change that describes its climate vulnerabilities and the action plans in water, agriculture/horticulture and livestock, energy, urban and rural habitats, forests, and biodiversity – to address various vulnerabilities. Sikkim Organic Mission can contribute to the conservation of agrobiodiversity, food security, the wellbeing of the indigenous communities, and sustainable agro-tourism.</p>	<p>Sharma, Ghanashyam</p>

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<p><b>Agroforestry, Agroecology and organic farming: a way to reach European Sustainability</b></p> <p>Europe is moving towards sustainable agriculture by implementing various frameworks, such as the EU Green Deal, Forest strategy, bioeconomy, circular economy, adaptation, farm to fork strategies among others. Besides new regulations involving for example the plantation of 3 billion trees or the biofertilizer development were also published in the recent years. Agroforestry as well as agroecology are central for the EU to reach the economic, environmental and social objectives of the CAP. The EU Green Deal aims at reaching a 25% of agricultural lands managed under organic farming (organic action plan) and reduce by at last 55% the GHG emissions by 2030, compared to 1990. The CAP represents the 31% of the total EU-27 budget in the EU 2021-2027. The next CAP will be linked to results-based payments, being the member states in charge of providing the results linked to different EU activities. The role of Agroforestry is linked to the different sections of the CAP such as the enhanced conditionality, but also the ecoschemes where agroforestry, agroecology and organic farming are the main tools to fulfil the areas of climate change mitigation, adaptation, protection or improvement of water quality, prevention of soil degradation, protection of biodiversity, actions for a sustainable and reduced use of pesticides and actions to enhance animal welfare associated with the CAP Strategic Plans designed by the 27 EU member states. Agroforestry and agroecology practices are not clearly recognized as such in Europe but promoted with different names. Organic farming is the most extensive farming system promoted in the EU with more than 95% of the Rural Development Programmes funding it. Agroforestry is mostly funded in Spain, France, Italy and Romania. Also the various forms of agroecology are promoted in the EU such as legume rotation, winter catch crops or mixed culture and polyculture.</p>	<p>Mosquera, Maria José Javier, Santiago Freijanes Alvarez-Lopez, Vanessa Javier, Rodriguez-Rigueiro Tamara, Franco Ferreiro-Dominguez, Nuria</p>
<p><b>Possibilities for scaling up the climate-smart village model in Senegal: Opportunities for inclusive transformative agriculture</b></p> <p>The need to transform agriculture to adapt to climate change is pressing in West Africa. The Senegalese government has adhered to the promotion of Climate-Smart Agriculture (CSA) launched by the international community as a set of solutions. Since 2011, Senegal has successfully implemented a holistic model of a "Climate Smart Village" (CSV) in Kaffrine in collaboration with its partners. The CSV is already recognized as a good practice of resilience in Senegal and West Africa, with advantages in terms of political will and public will. Previous analyses of the opportunities to scale up CSV have not closely examined the governance approaches, applicability, and socio-economic attractiveness of CSA practices to policies, projects and programs. The aim of this document is to fill this gap. Based on practical cases in the field, the study applies the comparative analysis of CSA governance models and assesses their impact on the sustainability and engagement of men, women and young people. On the basis of a grid, it evaluates, beyond the technique, the applicability and attractiveness of the promoted CSA practices. Semi-structured interviews and documents are the sources of data and information. The analysis identifies opportunities to build an inclusive and sustainable bottom-up governance model. It compiles a directory of CSA practices that are profitable and applicable for smallholder farmers. An improved governance model and availability of CSA practices, accompanied by ecological and socio-economic scientific evidence, will promote widespread adoption of the CSV model, with the potential to improve agricultural production and community livelihoods.</p>	<p>Sanogo, Diaminatou Diakhate, Pape Bilal Camara, Baba Ansoumana Diop, Mouhamadou Badji, Marcel Sall, Moussa Ouedraogo, Mathieu Raile, Eric D Bayala, Jules</p>



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<p><b>Policy coordination for promoting agroforestry in East Africa</b></p> <p>Food security and climate change continue to be the most critical issues in many parts of the world, especially in tropical developing countries. International and national researchers and policymakers have tried to find ways for sustainable agriculture and climate resilience to address these challenges simultaneously. Agroforestry, combining tree management and crop/animal production, gains recognition for its capacity to contribute to food security, long-term economic growth, and environmental conservation. However, wide-scale agroforestry adoption remains limited. Due to the combined aspect of agroforestry, the institutional accountability is indistinct, and the mandate of existing structures conflicts with one another. The necessity of effective policy implementation arises to increase the adoption and to scale up agroforestry practices. This study aims to examine the extent of coordination in national policies across agroforestry-related sectors using the cases of Kenya, Rwanda, and Uganda and compare the characteristics of each country from the perspective of policy coordination. Qualitative Document Analysis of relevant policies and plans are applied, and expert interviews with non-governmental and governmental players in each country are supplemented. Research findings provide a better understanding of sectoral coordination of agroforestry policies in East Africa towards sustainable development.</p>	<p>Son, Jeongeun Park, Mi Sun Lee, Hansol Min, Suyeon</p>
<p><b>Benefits of Increased Access to Forest Data: Lessons from Canada and Finland</b></p> <p>We ask how increased access to forest data can benefit actors and societies, using Finland and Alberta / Canada as examples. Forest data has value because forest ecosystem services have provisioning, regulating, and cultural values. Increased access to forest data – through open access or sharing -- may aid actors and societies to derive more and different values from forest ecosystem services. Nature protection may be enhanced, climate change may be better mitigated, businesses may develop innovative bioeconomy products and tourism services, indigenous cultures may strengthen, and social conflicts may lessen. Forest data alone is not particularly useful for actors, however, if one does not have legal rights to enjoy the ecosystem services, i.e. if one cannot base one's demand on law or contract. Increased access to forest data may strengthen or change the realization of existing environmental rights. Access to data may also spark demands for the clarification or renegotiation of individual or group rights. Accessible forest data and information, avenues for new forms of participation in forest governance (between citizens, indigenous groups and government), and spaces for trade in forest ecosystem services can be combined under digital forest platforms. Lessons from data sharing in Canada and open data from Finland extend to forestry and agro-forestry systems in other regions of the world.</p>	<p>Swallow, Brent Lähteenmäki-Uutela,, Anu Rantala, Salla Paloniemi, Riikka</p>

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<p><b>Fostering sustainable transitions in the Mexican livestock sector: Challenges and opportunities for institutional entrepreneurs</b></p> <p>Livestock activities have well documented social and environmental impacts that include rising greenhouse gas emissions, deforestation, land degradation, biodiversity loss, and poor animal welfare. Specialisation, management simplification and increased use of external inputs carry the blame for many of livestock's negative effects. Research shows that reincorporating diversity into agricultural landscapes, like integrating livestock and forestry, as silvopastoral systems do, enhances synergies between plants, animals and the environment that contribute to carbon sequestration, nutrient cycling, greater biodiversity, increased productivity and income diversification. However, adoption of these practices remains low in the agrifood regime. Building on institutional entrepreneurship and sustainability transitions scholarship, this paper uses a case study of the Mexican beef value chain to explore the field level conditions that undermine the escalation of silvopastoral systems in Mexico and discusses roles and opportunities for institutional entrepreneurs to engage in collective action for institutional change and landscape governance. Preliminary findings highlight institutional innovations at the federal policy level with a strong environmental rhetoric, but a lack of transversality between sectoral institutions and programs ends resulting in contradicting policies in practice. Additionally, most initiatives have historically focused on primary technical assistance, with limited efforts into governance issues and market development. Ingrained management practices and resistance to change, scarce and competing incentives, lack of farmers' associativity and ignorance of silvopastoral management practices and their benefits obstruct the sustainable transition of the sector. Opportunities for institutional entrepreneurs include improving coordination between environmental and agricultural policies, creating spaces for regional governance, increased participation of the private sector in multi-stakeholder platforms and increased efforts towards capacity building in aspects that involve social skills development and market commercialization.</p>	<p><b>Arguelles Gonzalez, Vivian</b>  <b>Galindo Maldonado, Francisco</b>  <b>Hickey, Gordon</b></p>
<p><b>For a universal classification of agroforestry</b></p> <p>Since the birth of agroforestry in the years 1970s, its classification is not yet stabilized. Different countries, different institutions, use different classifying rules. For instance, the USA use alley cropping, forest farming, riparian buffers, silvopasture and windbreaks as major agroforestry categories. In Europe, the following agroforestry typology has been proposed: trees within parcels (silvopastoral, silvoarable and agrosilvopastoral) and trees between parcels (linear agroforestry). For World Agroforestry (ICRAF), agroforestry comprises trees on farms and in agricultural landscapes, farming in forests and along forest margins and tree-crop production, including cocoa, coffee, rubber, and oil palm. This varied terminology makes it very difficult for the non -specialist to understand what is being talked about when one of these categories is used to describe an agroforestry practice. Agroforestry can be classified according to different criteria, e.g., structure (arrangement of components in time and space), function (productive or service role), socio-economic criteria (subsistence, commercial, large vs small farm), or ecological criteria (tropical, temperate, highlands, lowlands, etc.). Historically, structural criteria characterizing the presence of components have been preferred, i.e. agrisilviculture for trees and crops, silvopastoralism for trees and pasture or animals and agrosilvopastoralism for trees with both crops and pasture or animals. However, this basic classifying scheme has failed to translate into a pragmatic and widely accepted classification. It is possible to classify agroforestry according to simple structural criteria referring to what can be seen at the first glance. Five categories are necessary for</p>	<p><b>Torquebiau, Emmanuel</b>  <b>Balaguer, Fabien</b></p>



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<p>that: Crops under tree cover ; Agroforests ; Agroforestry in a linear arrangement ; Animal agroforestry ; Sequential agroforestry. These categories are presented, illustrated, and discussed. A universal classification of agroforestry will help designing policies leading to a better adoption of agroforestry practices.</p>	
<h3>J. Which Agroforestry for Arid Climates?</h3>	
<p><b>Disentangling the genetic diversity and population structure of shea tree in Cameroon and Chad by Genotyping By Sequencing (GBS) method</b></p> <p>Genetic diversity plays an important role in the adaptation and survival of species, and it is extremely important in tree species threatened by anthropogenic pressures, poor management or climate change. The shea tree or <i>Vitellaria</i> (<i>Vitellaria paradoxa</i> C. F. Gaertn.) is considered the second most important olive tree species in Africa and the most economically and culturally important tree species in the Sudano-Sahelian region. However, <i>Vitellaria</i> was listed as threatened, in 1998, by the International Union for Conservation of Nature. To develop a better conservation strategy for the species, a genotyping-by-sequencing approach was used to describe the diversity and the population structure of 490 trees from 20 populations of Cameroon and Chad and one outlying allopatric population from Mali. Genetic diversity (HE) was very low in these populations, ranging from 0.081 to 0.098 for the Cameroonian populations, from 0.050 to 0.093 for the Chadian populations and of 0.094 for the single Malian population. Population structure based on the pairwise <math>F_{ST}</math> shows similarities between some groups. The groups looked to be similar were: 1) Chadian populations, 2) Northd Cameroonian populations, 3) Far-North populations, 4) West Cameroonian and the single Malian population. Furthermore, the analysis of molecular variance (AMOVA) showed that the country of origin explained only 1.78% of the variance of the data, while most of the variation explained was within each population (78.24%). Our results suggest that emphasis of in situ conservation of shea tree genetic resources should be put within each country for the domestication in agroforestry of this green gold tree species to Western and Central African women.</p>	<p>Tchiabeu Kamtche, Kevin</p>
<p><b>Fruit and Tree Characteristics of <i>Vitellaria paradoxa</i> under Different Geomorphological Levels of the Hill at Djuie, Burkina Faso, West Africa</b></p> <p><i>Vitellaria paradoxa</i> C. Gaertn. is an agroforestry tree species and the marketing of its fruits and nuts provides substantial income for rural population in Burkina Faso. Despite the economic importance, fruits and nuts traits have been less investigated according to the relief in Burkina Faso. The aim of the study was to investigate variations in trees characteristics and fruits and nuts traits of a stand of <i>V. paradoxa</i> across four levels of the hill located at Djuie (11°11'58"N, 3°46'56"W) in Burkina Faso, West Africa, on July 2020. We randomly chose a total samples of 16 plots, 80 trees and 800 fruits and we mesured in each plot the tree height, circumference, fruit weight, lenght and thickness, nuts numbers/fruit during fructification stage from July to August 2020. The authors conducted an analysis of variance, a principal component analysis on tree characteristics and fruit traits variables and ascending hierarchical classification based on similarity indices. The results showed significant variations (<math>P&lt;0.001</math>) in tree height (CV=32.44%), stem circumference (CV=30.20%), fruit weight (CV=82.4%), nut number (CV=74.81%), fruit lenght (CV=74.18 %) and fruit thickness (CV=314.32%). The bottom level of the hill has the highest tree height, circumference, fruit weight, lenght and thickness and nuts numbers and the top level has the lowest ones. But the largest</p>	<p>Dao, Madjelia Cangré Ebou Montcho, Yvette Zoundi, Simon</p>

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<p>fruits belong to the top level (<math>3.30\text{cm} \pm 1.29</math>). Correlation analysis revealed no significant links between the trees characteristics and fruits traits. Tree morphological characteristics and fruits traits indicated two distinct groups between levels of the hill at Djuié. In conclusion, the study output provides an evidence of the genetic variability among <i>V. paradoxa</i> trees and fruits on the hill and hence the potential for future tree improvement programme.</p>	
<p><b>Jessour for a diversified and resilient agroecological systems to ensure food security and sustainable livelihoods in arid ecosystems</b></p> <p>For agricultural production, exploiting mountain slopes for rainwater runoff collection is a low-cost practice that supports sustainable agroecological systems and increases yield. To this day, people in rural communities continue to use an ancient and well-known system called Jessour to strengthen agricultural productive capacity and diversify their livelihoods. However, some effort is needed to maintain these systems and they require careful planning and engineering. A Jessour is composed of three parts, a sloping ground for collection, a terrace and an earth dyke. Jessour are mainly used for cultivating olive trees and sometimes dates, figs and almond trees. During rainy years, cereals (barley, wheat) and legumes (peas, lentils, broad beans) are cultivated between the trees. Once these crops are harvested, the crop residues are used as fodder for grazing livestock. Crop residues help fill feeding gaps, especially during the dry summer season. Livestock is continuously moved between trees, which allows rangelands to rest before winter dormancy. In arid areas of Southern Tunisia, Jessour are a vital agroecological system that support orchard plantation, annual crops and livestock, contribute to resilient, help sustain livelihoods for the majority of households and play an important role in ensuring food security under climate change and water scarcity. Therefore, greater attention is needed to establish and strengthen mechanisms that can make this proven technology more effective while conserving agrobiodiversity.</p>	<p>Louhaichi, Mounir Gamoun, Mouldi</p>
<p><b>Can the Assisted Natural Regeneration contribute to the renewal of <i>Faidherbia albida</i> parkland in Senegal?</b></p> <p>In the sudanian and sahelian zone, parklands are archetypal to agrarian landscape. Trees are selected, spared, fostered after land clearing for the various services they provide to the people. However, nowadays most of the African parklands are facing regeneration problems. The <i>Faidherbia albida</i> parkland among the Sereer of Senegal is exposed to such difficulties which stem from population growth, heavy land pressure, extension of cultivated areas, crop mechanization, weakening of governance structures. The drought years of the seventies and eighties caused a sharp rise of tree mortality. The return of the rains allowed to relax the biophysical constraints and now there are more saplings in the fields. However they are poorly protected and seldom survive ploughing or cattle grazing. Still, farmers have a vested interest in the <i>Faidherbia</i> for the fodder it provides and the improvement of soil fertility it allows. Furthermore, this tree is part of the traditional landscape and of the Sereer culture. This is why assisted natural regeneration (ANR) seems to be a relevant choice to rejuvenating the parkland. This communication will capitalize on the work conducted in the RAMSES research project. This project aims at promoting parklands agroecological intensification, including the sereer <i>Faidherbia</i> parkland. After carrying an inventory, documenting and analyzing the various project, past or present, using ARN in the region we will characterize their conditions for success or failure. We will use an extended framework which will allow us to move from the merely technical vision of ARN to take into account socio-economic variables and anthropological data: place of farming in the household activity system, use of wood and non wood trees products, land tenure,</p>	<p>Bidou, Jean Etienne Droy, Isabelle Lavigne Delville, Philippe Sanogo, Diaminatou Seghieri, Josiane</p>

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governance structures. The aim is to identify the conditions of success or failure of these projects.	
<h3>K. Which Agroforestry for Annual Crops?</h3>	
<p><b>Survival, growth, and stem quality of trees planted in shelterbelts in an intensive agricultural area in southern Québec</b></p> <p>Good survival and early growth of selected tree species without wood defects are critical to maximise the ecosystem services that are provided by trees in agroforestry systems. Therefore, this study aimed to understand how abiotic factors, species selection, and management practices interact to affect tree survival, growth, and stem quality in shelterbelts. Tree establishment success (survival and growth rate) of all species and stem defects of hardwoods were assessed for 74 shelterbelts (windbreaks and tree riparian buffers with a mean age of 15 years old) distributed on 38 farms in the Montérégie region (Québec, Canada). Every shelterbelt surrounded a cropped field that was used to produce different annual cash crops and hay meadows in rotation. Climate conditions, soil pH, soil texture, tree spacing, shelterbelt width, tree protection against deer and rodents, methods of vegetation control, and frequency of annual crops in adjacent fields were determined. A total of 34 tree species (chiefly native) occurring in a wide variety of arrangements were sampled. Tree composition and management practices related to tree establishment varied widely among shelterbelts. Tree survival and growth were highly species-dependent and site-specific. Results will allow us to identify the best practices to ensure optimal establishment success and stem quality for trees in shelterbelts and inform on expected tree growth rates for different growing conditions in these shelterbelt systems.</p>	<p>Mathieu, Antoine Rivest, David Cogliastro, Alain</p>
<p><b>Which agroforestry tree species meet the challenges of climate change mitigation and soil fertility restoration in the Highlands of Madagascar?</b></p> <p>Within agroforestry systems, trees greatly contribute to soil carbon sequestration. An important diversity of tree species can be used when designing agroforestry systems. While the effect of tree presence on soil carbon stocks is widely recognized, we still know little of how this contribution varies according to tree species. In the present study, we aimed at quantifying the soil carbon stocks derived from three main tree species: <i>Eucalyptus robusta</i>, <i>Coffea arabica</i>, and <i>Citrus clementina</i>, used in rainfed rice-based agroforestry in the Highlands of Madagascar. A full factorial mesocosm experiment was realized, with seedlings of the tree species planted in a Ferralsol. Natural <math>\delta^{13}\text{C}</math> abundance in soil was measured to assess tree-derived carbon. Six months after planting, <i>Eucalyptus robusta</i> was the species exhibiting the highest tree-derived carbon (5,52 MgC ha<sup>-1</sup>). The tree-derived carbon from the two other tree species was 1.02 MgC ha<sup>-1</sup> and 0,53 MgC ha<sup>-1</sup> respectively for <i>Citrus clementina</i> and <i>Coffea Arabica</i>. The difference in soil C sequestration among tree species was highly explained by differential root biomass. Tree root biomass was significantly correlated with soil <math>\delta^{13}\text{C}</math> (<math>R^2=0.65</math>, <math>p\text{-value}&lt;0.001</math>). Our experiment assay highlighted the differential contributions of tree species to soil carbon sequestration at the earlier stage of the agroforestry setting. The capacity of each tree soil carbon sequestration constituted one criterion for evaluating the tree species potential to address agronomic and ecological objectives of agroforestry adoption.</p>	<p>Rasoarinaivo, Angelina Razafimbelo, Tantely Blanchart, Eric Chapuis-Lardy, Lydie Chevallier, Tiphaine Rabearison, Toky Jeriniaina Bouillet, Jean Pierre Trap, Jean</p>

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<p><b>The cultivation of <i>Citrullus lanatus</i> (Thunb.) in the Central Groundnut Basin of Senegal: adoption and agro-ecological consequences</b></p> <p><i>Citrullus lanatus</i> cultivation is one of the adaptation strategies adopted by communities to cope climate change in the central groundnut basin of Senegal as is the case with groundnut cultivation, which has had negative agro-ecological consequences. This study aims to understand the reasons for the adoption and the agro-ecological consequences of <i>Citrullus lanatus</i> cultivation in the Groundnut Basin. Surveys were conducted among 30 adopters and 30 non-adopters and ecological inventories were conducted in 21 adopters' fields and 23 non-adopters' fields. The main reasons for adopting <i>Citrullus lanatus</i> cultivation among adopters were to increase and acquire income early. Adopters of <i>Citrullus lanatus</i> cultivation are more exposed to food insecurity than non-adopters if we consider the duration of annual consumption of their agricultural products (7% of adopters versus 21% of non-adopters live on their agricultural production beyond 12 months). In this area, <i>Citrullus lanatus</i> cultivation is an intensive conventional agricultural practice with nearly 64% of the adopters growing the crop twice in the same cropping season using ploughing, chemical fertilizers and pesticides. Ecologically, floristic diversity is higher in the field of non-adopters than in those of adopters with 34 species in 29 genus and 16 families compared to 19 species in 17 genus and 10 families. The same is also the case for the regeneration capacity, which is better in the fields of non-adopters of <i>Citrullus lanatus</i> than in those of adopters of this crop (220.43 ind/ha against 105.39 ind/ha). The cultivation of <i>Citrullus lanatus</i> certainly allows for an early improvement in household income, but it negatively affects the productivity and the regeneration potential of the fields.</p>	<p>Sanogo, Diaminatou Ndiaye, Ndèye Katérine Badji, Marcel Seghieri, Josiane</p>
<p><b>Agroforestry systems increase productivity, profitability and soil fertility of degraded ecosystems: Experience from a sandbar of northern Bangladesh</b></p> <p>Agroforestry is one of the potential agricultural practices that provide diversified structural components and assist in coping with the pessimistic impacts of climate change. Agroforestry systems focused on natural resource management systems might improve the degraded ecosystems (e.g. sandbars). It is also imperative to identify the suitable tree-crop combination that upholds total productivity, economic return and improves soil fertility. The present study evaluates the performance of vegetables (cauliflower and okra) and year-round spices (ginger and turmeric) under the early stage of mango-based agroforestry systems (MAFS). The sole cropping of vegetables, spices, and trees was treated as control. The findings of the study revealed that the growth and yield attributing characters of spices and vegetables were less inhibited by the MAFS. These results suggest that sunlight can pass through the small canopy of young mango trees which is essential for annual crops. The maximum yield of spices was noted in MAFS due to the shade-loving nature of spice crops while the maximum yield of vegetable crops was found in the control treatment. However, due to the presence of trees, total productivity was maximum in MAFS. The highest benefit-cost ratio was found in the mango-turmeric-cauliflower (5.78) treatment combination followed by in the mango-turmeric-okra (4.92) crop combination. The market value of spice and vegetables contributed to the higher benefit-cost ratio. Farmers mentioned that the improvement of transportation and marketing facilities might attribute to achieving higher economic returns. The total soil nitrogen (TN) and organic matter (SOM) were found higher in MAFS contrasted to its control. The tree prunings, litter, and crop residues were incorporated into the soil resulted in the improvement of soil properties. Hence, this study suggests that fruit tree-based agroforestry systems might be a potential option for the improvement of the degraded ecosystems while ensuring productivity and profitability.</p>	<p>Hanif, Md Abu</p>

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<p><b>Open Growth of Three Oak Species in a corn/soybean Agroforestry Practice</b></p> <p>Trees are intentionally integrated in agroforestry for numerous ecosystem services (ES) including environmental, production, and economic benefits. The growth of trees is believed to be different in open systems as compared to forests. Open tree growth data is limited thus restricting integration of trees in agroforestry for ES. Growth of Pin (<i>Quercus palustris</i> Muenchh.), swamp white (<i>Q. bicolor</i> Willd.), and bur oak (<i>Q. macrocarpa</i> Michx.) were evaluated for 23 years in an agroforestry alley cropping watershed in Northern Missouri, USA. Containerized oak seedlings were planted in the center of 4.5-m wide contour grass-legume strips at 3-m spacing with a corn (<i>Zea mays</i> L.)-soybean (<i>Glycine max</i> (L.) Merr.) rotation. Survival, height, and diameter (dbh and 10-cm) were recorded from 1999 to 2020. From 2001 onwards, pin oak showed significantly greater height than swamp oak and bur oak. Pin, swamp white, and bur oak heights in 2020 were 1149, 883, and 832 cm. Swamp oak showed significantly greater height than Bur oak from 2002 onwards. Average height growth rates from 1999 to 2020 were 49.3-, 36.9-, and 34.4-cm yr<sup>-1</sup> for pin oak, swamp white oak, and bur oak, respectively. For the respective tree species, the average dbh growth rates were 14-, 10-, and 9-mm yr<sup>-1</sup> for 2004-2020. Pin oak always had significantly greater dbh compared to bur oak, where swamp white oak started to show significantly greater dbh than bur oak from 2007 onwards. Similar patterns were observed for 10-cm diameter values and growth. Pin oak had significantly greater 10-cm diameter than swamp white oak and bur oak for 1999-2007. Results of the study suggest that pin oak and swamp white oak have a better potential for agroforestry in the Midwest than bur oak.</p>	<p>Udawatta, Ranjith Mendis, Sidath Salceda, Miguel Rankoth, Lalith Weerasekera, Chamara</p>
<p><b>Effects of the age of <i>Acacia auriculiformis</i> agroforestry fallows on soils and cassava crop yields on the Bateke Plateau in the Democratic Republic of the Congo</b></p> <p>Background: Agroforestry fallow consists of planting trees in order to restore soil fertility after a series of crops. This practice is encouraged because it would shorten the time of traditional fallows and increase soil productivity. Objectives and methods: This study verified these assumptions by exploring some little-studied aspects of this practice. More specifically, the objectives were to evaluate and compare the effects of agroforestry fallows with <i>Acacia auriculiformis</i> whose age classes were 1 to 3 years; 3 to 5 years and 5 to 7 years, as well as traditional 5-year fallows on soil fertility and carbon stocks as well as on cassava yields and the nutrient content of their leaves and flour. Results and discussion: The results obtained led to the conclusion that agroforestry fallows improve soil fertility and carbon stocks compared to traditional fallows. The age of agroforestry fallows did not influence these parameters. Regarding cassava trials, agroforestry fallows of at least 5 years old yielded higher tuber yields than other fallows and these were associated with high levels of potassium (K) contained in the crops. flour. The differences in the nutrient content of the leaves were not significant. Conclusion: Finally, the agroforestry fallows with <i>Acacia auriculiformis</i>, in particular those aged 5 and 7 years, showed better performance for the parameters evaluated during this study.</p>	<p>Kachaka, Etienne Yusufu Munson, Alison Poirier, Vincent Khasa, Damase</p>

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### L. Which Agroforestry for Commercial Perennial Crops and Trees?

#### **Optimization of planting methods for two perennial crops in the Lower St. Lawrence region: hybrid hazelnut and juniper**

Hazelnut and juniper production offers great socioeconomic potential for Canada as nearly all hazelnuts and juniper berries consumed in the country are currently imported. In 2020, more than 16,000 tons of hazelnuts valued at \$158 million were brought into Canada. Over 150 Canadian microdistilleries spend \$1,310,833 annually on imported juniper cones for the production of spirits (this figure includes both juniper cones and fennel seeds), while the annual cone consumption of these microdistilleries alone, not including that of large distilleries, is estimated at nearly 10 tons. The competitiveness of northern crops on the market—and particularly hazelnuts and juniper berries—is a determining factor in Canada's ability to reverse the current trend and position itself as a producer rather than an importer. Agricultural production management practices adapted to northern hybrid hazelnut varieties and juniper must therefore be developed. To meet these objectives, 23 nut groves and eight juniper plantations have been planted since 2018 in each of the regional county municipalities of the Lower St. Lawrence. From these planting sites, seven cultivars and 19 seed strains selected from hazelnut trees were compared in hardiness zones 3–4 and across three geomorphological zones, namely coastal, piedmont, and upper plateau. Nearly 2,000 junipers were planted on sites of different soil textural classes (sandy loam, loam, and clay loam) using two gravity irrigation strategies. Preliminary results indicate variation in the growth of the cultivars analyzed as well as differences depending on the type of mulch used. The issue of plant supply is addressed through in vitro hazelnut seedling production and juniper multiplication by taking cuttings.

Perron, Béatrice  
Charbonneau, Camille  
Primeau-Bureau, Félix  
Lavoie, Nicole  
Tardif, Maxim

#### **Cocoa4Future: A research in partnership project contributing to the agroecological and organizational transition of cocoa production in West Africa**

In 60 years, African cocoa production grew at the expense of forested areas that have practically disappeared in Côte d'Ivoire and Ghana. Besides, both countries are also currently concerned with ageing cocoa orchards whose rehabilitation is jeopardized by the cocoa swollen shoot virus. In the coming decades, climate change will also limit the areas suitable for cocoa farming. The unsustainability of cocoa production in West Africa will ultimately increase the vulnerability of cocoa farms relying on this crop. In such a challenging context, there is an urgent need to design and disseminate sound cocoa cropping and farming models, able to guarantee a decent livelihood for family farmers while avoiding environmentally detrimental practices. This is the aim of the Cocoa4Future project, which gathers Ivorian and Ghanaian research and training institutions, NGOs, several cooperatives and companies in the cocoa sector. Cocoa4Future proposes an ambitious scientific framework enabling these partners to conduct a broad range of research to i) disseminate agronomically and ecologically efficient and resilient agroforestry systems, ii) promote levers to ensure the socioeconomic sustainability of cocoa farms. Cocoa4Future combines two complementary and, so far, unseen approaches in the cocoa sector: i) an integrative approach with different levels of analyses: from the cocoa plot to the farm, from the cropping system to the cocoa production sector; ii) a multidisciplinary approach linking agronomy to technology, entomology to virology, advisory services to the cocoa value chain. It takes action in areas representative of the main cocoa growing regions in Côte d'Ivoire and Ghana and mobilizes networks of cocoa plantations

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and farms, which are closely connected. Results from the project aims at enabling the West African cocoa sector to meeting the major challenges it currently faces while - this time - placing people and the environment at the core of tomorrow's cocoa production.	
<p><b>Future Northern Forest Farms for Quebec and the North East of America</b></p> <p>Beyond the agricultural farms, a new production mode of food production is about to begin in Quebec, the forest farms, based on permaculture with elements of agroforestry, silvopastoralism and edible garden forests, and also inspired by many aspects of the First Nations art of living and their ways to make nature around them produce more wild foods. This new production mode will take a prominent place with time, considering the very various types of soils besides alluvial plains in all the Quebec's territory. A great amount of new edible resources will be produced in these forest farms, including unusual berries, wild vegetables and lettuces, northern nuts, wild roots, extractable flavors from trees, edible flowers and many more, without forgetting the food from hunting and fisheries. I invite you to discover some of these not-so well known treasure foods and to rethink about their possible permacultural installation depending on each natural microsite available.</p>	Perreault, Yvan
<p><b>Compatibility of <i>Cymbopogon flexuosus</i> as an aromatic and medicinal intercrop under <i>Populus deltoides</i> based agroforestry systems in northern India</b></p> <p>Diversification of crops under tree canopies is a win-win solution for sustainability and intensive land use, as it contributes pragmatically in all spheres to materialize the desired goals. Poplar (<i>Populus deltoides</i>) Bartr. based intercropping is a highly lucrative venture in northern India. Lemon grass (<i>Cymbopogon flexuosus</i>) is commercially cultivated to fulfill dwindling supplies. An experiment was conducted under 2 to 6-year-old poplar plantation to standardize the plant population of lemon grass for intercropping in poplar plantation and spacing of poplar for getting better productivity of herb. It was established at three spacings viz. 8 x 2.5 (S1), 7 x 3 paired at 2.5 (S2) and 5 x 3 m (S3). Lemon grass was transplanted at three spacings viz. 45 x 45, 45 x 60 and 60 x 60 cm under poplar and as sole crop. Poplar height, diameter at breast height, herb and oil yield of lemon grass and litterfall was recorded yearly. The increment in volume (0.40 to 1.19 m<sup>3</sup>) of poplar was significantly higher in S1 over the years. Herb yield of lemon grass was not significantly influenced by lemon grass spacing from 4th years onwards; however, the quantum of herb yield was higher in 45 x 60 cm throughout poplar rotation. The herb and oil yield of lemon grass was significantly lower in poplar plantation than sole crop. Litterfall addition was highest in S2 followed by S3 and S1 during different years. Soil organic carbon and available N, P and K improved under different spacings from initial levels (3.22 g/kg, 136.2, 13.72 and 188.4 kg/ha, respectively) after 6 years of planting and this increase was highest in S2 (38.8, 16.2, 32.9, 5.68%, respectively). Thus, poplar at a spacing of 8 x 2.5 m intercropped with lemongrass (45 x 60 cm) enhanced the productivity of the agroforestry system.</p>	<p>Kaur, Harmandeep Kaur, Navneet Gill, R.I.S Singh, Baljit</p>
<p><b>Tree breeding and planting as a business: How it is done around Mount Elgon, Uganda</b></p> <p>Efforts to restore the world forests and related tree resources are obviously significant and still increasing. Unfortunately, several of these efforts go to a waste when low quality seedlings are used to restore trees in degraded forests/agroforest systems. A survey was conducted around Mount Elgon in Uganda to assess the factors affecting production and planting of quality tree germplasm. The objectives were to i) identify the socio-economic drivers of actors in the tree planting industry, ii) document the actors practices and choices of trees planted and iii) determine the relationship between actors' socio-economic</p>	<p>Galabuzi, Charles Agaba, Hillary Carsan, Sammy Muthuri, Catherine</p>



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<p>factors, practices and choices of trees planted. A total of 150 people were engaged through semi-structured and key informant interviews. Data were analyzed in MINITAB 19. Results show that the tree breeding and planting as a business was dominated (84%) by a vibrant group of males between 15 and 40 years. Up to 60% of this group were illiterate and under-skilled in tree breeding and management on farms. The farmers comprised the most important actors, with higher interests in exotic than indigenous tree species. Almost 56% of the farmers were smallholders, planting trees based on farming perspectives and livelihood needs. Exotic tree species were preferred for quick economic returns while their native equivalent were preserved for basic livelihood needs such as supply of medicine, fruits, firewood and providing support for food crop. Fruit tree planting materials were mainly produced from stem and root suckers while their native alternatives were mainly raised from seed and wildings. We encourage the actors' cooperation during tree germplasm selection in order to meet performance expectations. The expectations include developing individual species regeneration protocols based on physical and climatic conditions of sites for seed collection and planting.</p>	
<p><b>Performance of four planted accessions of <i>Tamarindus indica</i> (Fabaceae) in the Groundnut Basin of Senegal</b></p> <p><i>Tamarindus indica</i> is a priority local forest food tree in the Sahel. It is an important source of income for many rural families. It is still in the wild, apart from a few specimens of the accessions recently introduced into the landscape of Sahelian villages. The objective of the present study is to investigate the performance of new accessions and the effect of grafting to shorten the entry into the fruiting period in order to improve biodiversity in agroforestry parklands and diversify the sources of income of small producers. The design was a randomized complete block with 5 replications. Each block was composed of 5 plants from 3 improved accessions of <i>T. indica</i> (TB3, Niger 309, Sweet) and one non-grafted control. Growth parameters (height, collar diameter, crown diameter and number of primary branches) were measured on all plants. The evaluation of fruiting potential was made on 5 plants of each accession in the first year and 10 plants in the second year. Cost-benefit analysis were carried out to assess the financial viability and economic profitability of planting these accessions of <i>T. indica</i>. The results show that the Sweet accession had the best growth performance compared to the Niger 309 and TB3. Fruiting of all accessions started in the second year after planting, except for the non-grafted one which started to bear fruit in the fourth year. The TB3 accession had higher average fruit production in 2017 and 2018 (120 kg ha<sup>-1</sup> and 640 kg ha<sup>-1</sup>). The cost-benefit analysis shows that planting of improved <i>T. indica</i> accessions is financially viable and economically profitable. The introduction of improved accessions of local fruit trees in agroforestry parklands can play an important role in food security, the resilience of small-scale farmers and the improvement of biodiversity in the landscape.</p>	<p>Sanogo, Diaminatou Dembele, Catherine Ky Camara, Baba Ansoumana Ba, Halimatou Sadyane Badji, Marcel Diop, Mouhamadou Bayala, Jules Sall, Moussa</p>
<p><b>Comparative analysis on the socio-ecological and economic potentials of traditional agroforestry systems in the eastern Himalaya</b></p> <p>Five different traditional agroforestry systems viz. farm-based, forest-based, <i>Alnus</i>-cardamom, forest-cardamom, and <i>Albizia</i>-mixed-tree-mandarin were studied in the Eastern Himalaya to evaluate and compare stand nutrient dynamics, N<sub>2</sub>-fixation, and cost-effectiveness about social and ecological resilience to the increasing externalities such as climate change. Further, extensive field research in 12 locations during 2011–2019 was carried out to investigate the causes of productivity decline of agroforestry systems and adaptations measures, using a combination of rapid rural appraisal, structured questionnaire, and field sampling techniques. Overall soil nutrient availability was highest in <i>Alnus</i>-cardamom systems, followed by <i>Albizia</i>-mandarin systems. N<sub>2</sub>-fixation in <i>Alnus</i>-cardamom</p>	<p>Sharma, Ghanashyam</p>

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<p>systems was highest (95 kg ha<sup>-1</sup>), followed by forest-based systems (59 kg ha<sup>-1</sup>), and lowest in forest-cardamom agroforestry systems (9.5 kg ha<sup>-1</sup>). Annual economic return was highest from Alnus-cardamom (US\$ 1895), followed by forest-cardamom (US\$ 1275), and Albizia-mandarin systems (US\$ 1166). The output-input ratio was highest in Alnus-cardamom (12.05) and lowest in forest-based agroforestry (4.21). The agroforestry systems are economically valuable, ecologically adaptive, and agro-climatically suitable in the eastern Himalayas. Productivity of traditional crops from 300 to 3000 m has declined by 10 - 40 % in the past 15-25 years. Study participants attributed the decline in farming to four broad types: biological, socioeconomic, institutional/governance-related, and environmental/climate change-related. Altered seasons, erratic or scanty rainfall, prolonged dry spells, shorter duration of rainfall events temperature increase, drying of Himalayan springs/streams, soil moisture loss, increasing instances of diseases and pests, and shift in the phenological calendar were prominent factors. The future socio-ecological and economic resilience of this research lies in the collective design and implementation of an integrated agroforestry scheme, considered by farmers, scientists, agricultural extensions agents, and policymakers alike.</p>	
<p><b>Developing a remote sensing-based monitoring system for quantitative and qualitative changes of traditional orchards in Hesse, Germany</b></p> <p>Traditional orchards are an important element of the cultural landscapes as they provide or enhance a wide range of ecosystem services, for example related to carbon sequestration, provision of food and biodiversity. In Germany, the number and area of such orchards are declining, and maintenance can be challenging. The monitoring of traditional orchards is quite labour intensive as they are rather small landscape elements with a scattered distribution. The main objective of our study is to explore how methods of remote sensing can contribute to a landscape scale monitoring. More specifically, we aim to identify qualitative and quantitative parameters specifically fitted to the characteristics of traditional orchards that can be derived from multitemporal airborne laserscanning (LiDAR) point clouds and aerial imagery at single tree and site level. Our study area is the Federal State of Hesse (Germany), and pre-studies are completed for selected sites in Hesse. We identified both quantitative (e.g. planting and removal of trees, gaps in tree rows, changes in tree density) and qualitative parameters (e.g. shrub encroachment, tree age classes) that are important for monitoring. We derived these parameters from publicly available LiDAR data as well as colour infrared and true-colour airborne images. We applied methods of remote sensing such as tree crown segmentation as well as machine learning using free and open source software to map the relevant parameters and tree properties. As reference information for the accuracy assessment, field data regarding these parameters was collected on site and single tree level. In a preliminary study, we segmented trees of a large traditional orchard area with an accuracy of 93 % (n = 949). Random Forest classifiers for the tree age classes successfully classified the vast majority of young and newly planted orchard trees and a majority of the mature and old ones. These and other preliminary results indicate many possibilities and some limitations of remote sensing to aid monitoring efforts of traditional orchards in Germany. In the future, we will apply our methods to more traditional orchards in Hesse and investigate the possibilities of drone imagery for monitoring efforts.</p>	<p>Schnepel, Niklas Grosse-Stoltenberg, André Kleinebecker, Till</p>

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<p><b>Do not forget that agroforestry can also provide wood, be it fuelwood or timber, for the benefit of populations! Examples in West and Central Africa</b></p> <p>Environmental services of agroforestry have been emphasised during last decade, such as carbon sequestration and biodiversity maintenance, and priorities given in the last climate COP 26 and IUCN summit reinforce these aspects. Other services, such as shade provision and soil improvement, water and pest management, are also highlighted. Wood production, be it fuelwood and charcoal, timber and lumber production, arts and crafts, is still critical for a large part of rural and urban populations in many African countries. Present agroforestry systems plays a large role in wood production. Improved agroforestry systems, such as cocoa agroforestry systems or planted fallows, could increase sustainable wood production, and could contribute to decrease pressure on natural forests, complementary to forest plantations. Examples of improved agroforestry systems developed in some West (Ivory Coast) and Central African (Cameroun, Congo Republic, Democratic Congo Republic) confirms the potential of such agroforestry systems for wood production, complementary to sustainable food production. Integration of fast growing trees, mainly nitrogen fixing trees (local or introduced species, such as acacia mangium) in agroforestry systems, as part of fallow systems, present many advantages: wood and charcoal production, soil nitrogen and organic fertility improvement, revenues for small peasants. These systems could be managed at peasant level without high investments. They could contribute to wood and charcoal supply for rural and urban population, including cities such as Abidjan, Brazzaville or Kinshasa. Traditional cocoa production systems have been developed under natural forest shade, integrating some timber trees. Present strategies intend to develop “zero deforestation” and sustainable cocoa production; integration of various tree species in cocoa farms contribute to adapted micro climate, but could also contribute to timber and lumber production, with adapted management. Wood production for rural and urban population should then not be forgot, complementary to other food and services provided by agroforestry systems.</p>	<p>Mallet, Bernard Pity, Balle Njoukam, Raphael Peltier, Regis Wencelius, Francois</p>
<p><b>Saving the Remaining Forest in Ghana: Evidence from Cocoa Agroforestry System</b></p> <p>Ghana is one country that comes to mind when cocoa is mentioned. Cocoa subsector employs over 800,000 families. Ghana loses 65,000ha per annum with cocoa farming been alleged as a contributing factor. The current trend indicates that cocoa farmers in Ghana are drifting from forest shaded system to the no shade. This system is adding up to the high rate of deforestation, biodiversity loss, input demand, short productive life and low yield over time. It is quite apparent that with dwindling forests for new planting, cocoa agroforestry holds the key to future outputs and productivity in cocoa production. There is a gap in knowledge on understanding interactions between native tree species and cocoa. The research therefore aims at determining the yield trends in cocoa under different forest trees level. Multi stage sampling technique was employed to selected 300 cocoa farmers in the study area. Descriptive statistics and inferential analysis where used to analyze the data. Yield curve model was also adopted to determine the yield trend for various cocoa agroforestry systems. From the analysis, the R square value obtained under the no shade, low shade, medium shade and heavy shade are 77%, 61%, 53% and 56%, respectively. The highest average yield per hectare was attained for the no shade in year 16 (794 kg ha<sup>-1</sup>), for the low shade in year 22 (696 kg ha<sup>-1</sup>), for the medium shade in year 19 (735 kg ha<sup>-1</sup>) and for the cocoa under heavy shade in year 15 (546 kg ha<sup>-1</sup>). The conclusion of the study is that, although the no shade cocoa system has higher yields, it is input demanding, environmentally unfriendly and has short productive life. Therefore, the most</p>	<p>Twumasi-Ankra, Boakye Twumasi-Ankra, Angella Enoch Brefo, Mensah Nunoo, Isaac</p>

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<p>effective way of maintaining the remaining forest cover, optimizing ecological, economic, and social outcomes and therefore need to be promoted in Ghana.</p>	
<p><b>Effect of shade trees on American leaf spot disease incidence and intensity in a coffee agroforestry system</b></p> <p>American leaf spot disease caused by <i>Mycena citricolor</i> is a coffee fungal disease in Latin America that can lead to yield losses. Native to the area, American leaf spot disease can infect not only coffee, but also weeds and shade trees, making it hard to control. In this study, we investigate the potential effects of shade trees on American leaf spot disease in an organic coffee agroforestry system in southern Mexico based on seven months of sampling for disease incidence and intensity and data on shade tree distribution. Although low variation in disease intensities is explained by shade tree diversity, general linear model shows significantly negative relationship of diversity with the disease and no effect of tree density. We then compared disease incidence and intensity on coffee bushes under <i>Inga</i> spp., nitrogen fixing trees commonly found in coffee farms, <i>Alchornea latifolia</i>, a second common shade tree in the study site, and other shade trees including fruit trees. Chi-squared test and Kruskal-Wallis rank sum test show no significant difference in disease incidence for different tree types. T-test by tree types shows significantly higher disease intensities under <i>Inga</i> spp. than other shade trees, possibly due to the favorable microclimate conditions under <i>Inga</i> trees in the farm. The results suggest that higher shade tree density does not necessarily promote fungal diseases, while diversity could play a positive role on pathogen control in coffee agroforestry system. A possible trade-off between nutrient addition by <i>Inga</i> spp. and shade levels for nitrogen fixing trees may be present, and further studies examining independent factors associated with ecosystem functions of shade trees can inform management in coffee farms for fungal disease control.</p>	<p>Su, Chenyang Vandermeer, John Perfecto, Ivette</p>
<p><b>Silvimediculture - A Promising Agroforestry Model for Conservation and Commercial Cultivation of Medicinal plants in India</b></p> <p>Agriculture has been the main stay of India's economy and has contributed adequately to the Gross Domestic Product of the country. Since her independence in 1947, the country has emerged from the status of food deficient country to food surplus country owing to various developments that have taken place in the agricultural sector over the last seven decades. Being a sub tropical country, India has been endowed with rich floral and faunal genetic resources spread across various agroecological zones which includes a huge array of medicinal plant species. However current trends of increasing human population, diminishing agricultural land area due to climatic and socio-economic influences in the developing countries necessitate the need for integration of various components in unit land area. Among the various options available, agroforestry has been observed to be the most viable alternative to meet our future demands for food and wood besides providing various indirect ecosystem services. In India, most of the naturally grown medicinal and aromatic plant wealth is found in the in reserved and protected forests which are out of reach for public utility owing to the existing guidelines of National Forest Policy 1988, National Agroforestry Policy 2014 and forest legislations. Botanical Survey of India reports that the country is home to more than 8000 species of medicinal plants whereas on the global scale, though 12.5% of the 4,22,000 plant species documented worldwide are reported to have medicinal values, only a few hundred are known to be under cultivation. Albeit there is enough richness in the biodiversity of medicinal plants under natural conditions in India, commercial cultivation in farm lands is not practised in most of the medicinal plant species barring a few exceptions. With dwindling supplies from natural sources and increasing global demand, medicinal and</p>	<p>Jude Sudhagar, Rajadorai Hemalatha, Palanivel Ramah, Kandasamy Sekar, Iyyapillai</p>

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<p>aromatic plants need to be cultivated on a commercial scale to ensure their regular and sustained supply as well as to ensure their conservation without causing any negative impact to their genetic base. Importance and the economic and pharmaceutical values of indigenous medicinal plants have been documented in India's native systems of medicine viz. Ayurveda and Siddha. However, pattern of land-holdings, lack of domestication and paucity of package of practices for many medicinal plants have been the factors for the lack of commercial cultivation on an extensive scale. Hence, introducing compatible medicinal plants through Agroforestry in the form of Silvimediculture will open up a new vista and encourage such cultivation practices among the farmers with small and marginal holdings. Many tropical medicinal plants are well adapted to partial shading, moist soil, high relative humidity and mild temperatures allowing them to be intercropped with compatible tree species. Short stature and short cycle of medicinal plants particularly make them suitable for intercropping especially during the initial growth phase of trees in Agroforestry. Duration upto which medicinal plants can be intercropped in Silvimediculture with a given tree species depends on the size and intensity of the tree's canopy shade, tree spacing and crop management, pruning of tree branches and nature of the intercrops. Shade tolerant and rhizomatous medicinal plants can be successfully grown on a long term basis in Silvimediculture model of agroforestry. Since most of the medicinal crops are under different stages of domestication, Silvimediculture offers an immense scope for further improvement in productivity and adaptability which provides an opportunity for increasing the net returns per unit area.</p>	
<p><b>Case study: Identifying mechanisms for growth of the elderberry industry in Missouri</b></p> <p>American Elderberry (<i>Sambucus canadensis</i>) is a multi-stemmed shrub native to North America. Elderberry fruit and flowers are widely used for their health-promoting benefits. The berries are currently used as an ingredient in juices, wines, teas, jellies, and supplements for immune health. While elderberry is a novel crop, its sales in multiple market channels and adoption among small-scale farms continue to see significant growth. Missouri is now the number one producer of elderberry in the United States. Likely contributors to the growth of elderberry production in Missouri include the suitability of production sites, availability of improved cultivars, cooperative arrangements, and processing infrastructure, as well as consumers' increased desire for immune-boosting products. A case study approach will be used to explore the mechanisms that have contributed to the growth of the elderberry industry in Missouri. The purpose of the case study will be to demonstrate the different aspects of elderberry production and marketing in Missouri and to explore how those aspects relate to one another. Methodology will include a social network analysis approach to highlight these relationships. Semi-structured interviews will be used to understand elderberry production and marketing in the state. Interviews will be conducted with "network actors" that include directors of elderberry processing and cooperative organizations, elderberry producers, and managers of retail outlets that sell elderberry products. Further interviews will be conducted with other "network actors" identified by initial interviewees as important actors in the growth of the elderberry industry. Results from the case study will identify important concepts and mechanisms that can help inform future research directions for exploring the adoptions and marketing of novel crops.</p>	<p>Caruthers, Andria Lovell, Sarah</p>



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<p><b>Timber and fruit trees: an added value in cacao-based agroforestry systems in Alto Beni, Bolivia</b></p> <p>Cacao agroforestry systems offer a wide range of ecosystem services beside food and timber production, such as biodiversity, carbon sequestration, microclimate regulation, water infiltration etc. which makes them interesting for farmers as well as for society. In many cases the mid to long-term benefit for farmers from the shade trees is not known. To assess the added value of timber and fruit trees, 16 smallholder cacao agroforestry fields in Alto Beni, Bolivia were selected in 2017 with the criteria of having dynamic agroforestry or diverse agroforestry systems implemented. Fields were georeferenced and tree inventories established. Quantitative and qualitative data of the timber trees were taken. The farmers were interviewed concerning the fruit tree productivity and use of the harvest. The regulative governmental entity for timber tree management was interviewed for assessment of the timber value chain. The cacao agroforestry plantations have an average age of 18 years. For the total of 2'941 timber trees the species were identified (72), 20% of it were <i>Swietenia macrophylla</i>, which makes it the most popular timber species. Followed by <i>Myroxylon balsamum</i>, <i>Amburana cearensis</i> and <i>Centrolobium ochroxylum</i>. The average timber tree density was 154 trees/ha and the standing timber volume was 38.8 m<sup>3</sup>/ha. The value of the standing timber was evaluated in average of 12'947 USD/ha. This value needs to be reduced due to lack of professional timber processing. Most numerous fruit are banana, followed by the fruit trees of <i>Bactris gasipaes</i>, <i>Oenocarpus bataua</i>, citrics and <i>Garcinia gardneriana</i>. There is a marked difference in fruit tree density according the agroforestry system, dynamic agroforestry systems harbor much more fruit trees compared to the simpler agroforestry systems which have the focus on timber. With the aim to increase farmer's income from timber as well from fruit trees the value chains need to be strengthened.</p>	<p>Schneider, Monika Baumann, Matthias Choque Martela, Beatrice Armengot, Laura Milz, Joachim Schneidewind, Ulf Rüegg, Johanna</p>
<p><b>Multifunctionality of cacao production systems: avoiding tree-site mismatching</b></p> <p>In the context of climate change, the adoption of climate-smart production system to sustain cacao production and environmental services is urgently needed [1]. Cacao agroforestry systems are expected to be an appropriate strategy for achieving multifunctional land use [2]. However, multifunctionality within the spatial and temporal scales of agroforestry is highly complex, context-dependent and occasionally inconsistent [3]. As quantitative studies are limited, generally applicable shade recommendations remain contested and difficult [4, 5]. For example, the combination of fast-growing trees and cacao in the water-limited region has been shown to increase, rather than decrease, climate-related cacao mortality risks [6]. We used the tree-crop-soil interaction model WaNuLCAS to explore the best possible management option in cacao production systems based on the Land Equivalent Ratio for multifunctionality (LERM). LERM -is a combination of LER for provisioning function (LERP) and that for regulating services (LERR). The scenarios also evaluated economic performance and tested it under various climate regions of Indonesia. Our specific research questions were: (1) How do the above- and belowground architecture and functional traits of potential cacao agroforestry components relate to expected yields, and the water and carbon balances of the soil-plant system? (2) To what degree can cacao agroforestry systems be a strategy to reduce land hunger through the improvement of LER above 1 on land multifunctionality services (LERM) – which are indicated by higher LER for cacao production (LERP), and water balance and soil carbon stocks (LERR)? and (3) How are the economic performance indicators (NPV, RtL, and BCR) reflecting the farmer risk and potential benefits in agroforestry systems compared to cacao monoculture? References: 1. Bunn, C., T. Talsma, and F. Castro, Climate Change Impacts in Indonesian Cocoa Area. 2017,</p>	<p>Saputra, Danny Dwi Sari, Rika Ratna Khasanah, Ni'matul Hairiah, Kurniatun Suprayogo, Didik Van Noordwijk, Meine</p>

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<p><b>Cocoa Agroforestry System (CAS) at the Centre of Cameroon's Roadmap to Deforestation-Free Cocoa</b></p> <p>The 2021 IPCC report highlights that anthropogenic climate change impacts results in increased frequency and severity of extremes climatic events. According to Batsi et al. (2020), most important drivers of biodiversity loss and the associated ecosystem services at landscape-scale are driven by land-use activities, such as forest clearing, subsistence agriculture, and agriculture intensification. During the Cop 26, 141 member states representing 90.94% of the world's forest cover, signed the Glasgow Declaration, committing to halting and reversing deforestation and land degradation by 2030. Although cocoa production has been identified among the drivers of deforestation in Cameroon, being the 4th cocoa producer in the world, the government raised ambitions of increasing production from about 275, 000 tones/year to 640,000 tones/year by 2030. The forest constituting about 46% of landcover and 11% of the Congo Basin Forest block has a deforestation rate of about 0.27%, positioning Cameroon as vulnerable to deforestation in the Congo basin. The government, battling with climate change challenges and with the need to ensure a sustainable cocoa sector, engaged the Roadmap to Deforestation-Free Cocoa (RDFC) Initiative which seeks to protect and restore the natural forest, promote sustainably production and trade of cocoa, and ensure community engagement and livelihood enhancement for cocoa farmers. This study builds on secondary data on cocoa agroforestry systems (CAS) research studies in Cameroon and the outcomes and recommendations of technical workshops and stakeholder consultations of the RDFC process. Though CAS will perform differently in different agroecological zones, scientific studies conducted demonstrates the strong potential of CAS to boost cocoa production, contribute to biodiversity conservation, emission reduction as well as livelihood enhancement. In the roadmap process, stakeholder elaborated and signed the Joint Framework for Action as one of its key tools in which CAS, was recommended as the technic for all the 3 pillars of the roadmap.</p>	<p>Ngwa, Elvis Suh Akongnwi</p>
<p><b>Influence of shade trees and bananas on coffee yield and quality in different coffee production systems in Tanzania</b></p> <p>Global coffee consumption is on the rise, but production conditions are worsening due to climate change. Farmers are facing yield losses as well as a reduction in coffee quality. Appropriate adaptation measures are necessary to overcome the challenges posed by climate change. By assessing the effect of multiple shade components on coffee yield and quality in two coffee production systems at Mt. Kilimanjaro, we aim to improve understanding of the potentials of shade in increasing resilience of coffee production systems in the face of climate change. Different components of shade, including shade density, tree and banana density as well as distance to the closest tree were recorded. We estimated the total yield</p>	<p>Wagner, Sigrun Preziosi, Richard</p>



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<p>of 215 coffee plants in 2018 and of 430 plants in 2019. In both years ripe berries were harvested and aspects of physical quality measured. Our results suggest that increasing shade density has a complex effect on coffee production, as a multitude of interacting factors determine potential benefits or disadvantages. While there might be a slight yield reduction under excessively high shade density, as observed in homegardens, a proper management regime can help reduce potential trade-offs. If coffee plants are provided with sufficient nutrients and water, as is the case in coffee plantations, even high shade densities would not negatively impact coffee yield. Some positive effects of shade have been observed for coffee quality. Shade trees were beneficial for the size and weight of coffee beans. Banana plants seem to be favourable during bean development and filling, as the percentage of floating beans (i.e. poorly developed beans) was reduced. This might be very beneficial for the farmers, as coffee quality is important for the price they can obtain.</p>	
<p><b>Post-harvest handling practices of black walnuts for improved germination</b> Black walnut (<i>Juglans nigra</i>) is an economically important North American tree valued both for its lumber and edible nuts. Successful establishment of nut-production orchards is frequently hindered by poor and inconsistent seed germination, both in the nursery and in the field. Studies were conducted 1) to develop an understanding of the need (or not) for black walnut seeds to “cure” or dry before stratification, and to what extent viable seed-nuts can tolerate drying, and 2) to corroborate the validity of the “float test” that is commonly used to sort viable from inviable seeds – the assumption being that bad seeds float and good seeds sink. The tetrazolium seed viability assay was also evaluated to determine if it could facilitate sorting viable from inviable seeds. Experiments were conducted using nuts from both non-improved and improved genotypes in 2019 and 2020. In experiment one, seeds were dried at 37 °C for different durations after which subsets were evaluated for moisture content, tetrazolium response, and germination. In experiment two, seeds were floated in water to determine buoyancy. Seeds that sank were immediately separated, whereas seeds that floated were left for 24 hours and thereafter sorted into floaters or sinkers. Subsets of these three seed categories were stratified and germinated. Results suggest that black walnut seeds require a minimum of 20% moisture to remain viable. The float test was confirmed as a relatively reliable method to remove large numbers of inviable seeds from a seed-lot. Germination of seeds that initially sank ranged from 20-60%, whereas germination of seeds that persistently floated was around 1%. However, germination of seeds that initially floated then sank within 24 hours ranged from 10-49%. Therefore, while the common practice of discarding floating seeds may have merit, many viable seeds may also be discarded. The tetrazolium assay consistently overestimated germination rate.</p>	<p>Schuessler, Benjamin Hwang, Chin-Feng Revord, Ronald Chism, Jay Thomas, Andrew</p>
<h3>M. Which Agroforestry for Integrating Livestock to Trees and Crops?</h3>	
<p><b>Fodder trees restoration and recruitment: a climate change pastoral adaptation in the Gran Paradiso National Park (italian western Alps)</b> Use fodder trees is a traditional method to provide an additional feed ration for bred herbivores in Europe and in the Mediterranean basin. Tree species like ashes (<i>Fraxinus excelsior</i>), maples (<i>Acer spp</i>), elms (<i>Ulmus spp</i>), mulberries (<i>Morus spp</i>), but also oaks and other broadleaved trees are specially pruned to foster this practices since Neolithic age. With the progress of intensive and mechanized agriculture from the second half of XX century pollarding practices have been</p>	<p>Paolo, Varese Federico, Bacci</p>

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<p>gradually abandoned and traditional rural landscapes deeply simplified. In the Alps mountain meadows have been colonized by secondary woods often originated by abandoned fodder trees seedlings. In the Gran Paradiso National Park the LIFE european project «Pastoralp» concerning adaptive climate policies in pastoralism highlighted the chance to focus adaptive practices with a sylvo-pastoral approach in conjunction with pastoral management measures. A study area is identified in the montane level of the Orco valley (TO) in correspondence with high density of ancient fodder trees near alpages with still active pastoral activities (small and medium family farms). A U.A.V. based sampling inventory and thematic cartography is promoted to assess management units and differentiated research approaches. Restoration of ancient ashes and maples is executed not only for fodder and pastoral purposes but also for landscape and biodiversity conservation; the presence of monumental trees in correspondence of tourist trails and villages poses indeed substantial security problems. In parallel a biodiversity survey has been implemented towards saproxilic and xylophages beetles, bats and birds that can occupy old trees. The recruitment of new fodder trees and the ability to pollard and manage them over the years request a participated approach wich joins traditional manual skills and young generations support: therefore not only recovery traditional works, but also identify new perspectives and innovative ways to live in the alpine environment.</p>	
<p><b>The effect of agroforestry trees on productivity, nutritional quality and water use on guinea grass</b></p> <p>Livestock smallholder farmers in South Africa frequently encounter inadequate and poor quality of fodder during the dry season. The main purpose of the study was to evaluate the effect of intercropping <i>Sesbania sesban</i> (SS) and pigeonpea (CC) (<i>Cajanus cajan</i> (L.) Millsp) on the dry biomass matter yield (DBMY), nutritional quality and water use of Guinea grass (<i>Megathyrus maximus</i>) (MM). The main treatments were SS+MM, CC+MM, SS,CC and MM. Soil water mark sensors were installed 0.2; 0.5; 1.2 m within each of the three replicates to monitor soil water tensions (kPa), which was reported as volumetric water content. Crude Protein (CP) was determined using a Leco Trumac Nitrogen Analyser employing the Dumas combustion method. The results were in the order <math>SS + MM (2130 \text{ kg ha}^{-1}) &lt; CC + MM (4066 \text{ kg ha}^{-1}) \leq MM (4991 \text{ kg ha}^{-1})</math>. Thus SS reduced MM grass yield by 4.5 times compared to 1.2 times with CC. Considering the whole agroforestry system, CC + MM (<math>9209 \text{ kg ha}^{-1}</math>) produced the highest fodder yield and was more water use efficient (WUE) (<math>16.8 \text{ kg mm}^{-1} \text{ ha}^{-1}</math>). Agroforestry trees intercropped with MM increased nutritional quality (CP). The results were as follows <math>SS (21.93\%) &gt; CC (16.51\%) &gt; SS + MM (11.63\%) \geq CC + MM (11.36\%) &gt; MM (3.05\%)</math>. The <math>&gt; 10\%</math> CP fodder produced from the cropping systems with agroforestry trees is of great significance as it is substantially higher than the minimum requirements for most livestock. Intercropping CC with MM was the most productive, highest nutritional quality and WUE. MM is low in CP and should therefore be intercropped with legume trees. This can act as a supplement for farmers who purchase concentrates thereby providing a balanced diet at lower cost.</p>	<p>Musokwa, Misheck Mafongoya, Paramu Chirwa, Paxie</p>
<p><b>Evaluation of silvopastoralism and cattle supplementation as strategies to promote sustainable dairy production in the Peruvian Amazon</b></p> <p>Livestock in the Peruvian Amazon region is mostly produced by small-scale farmers on degraded pastureland. As it has been associated to deforestation, alternatives for sustainable livestock production should be explored. Hence, the objective of the present study was to evaluate the technical and economic aspects of implementing two alternative strategies to promote a sustainable dairy production in the northern Peruvian Amazon using the concept of circular economy. Scenario modeling using local data was carried out considering average</p>	<p>Ruiz Llontop, Deysi Yenny Fuentes Navarro, Eduardo Gómez Bravo, Carlos</p>

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<p>dairy farms size and typology. Two different strategies were evaluated: a) Partial replacement of degraded pastureland areas by silvopastoralism (alley arrangements of guazuma crinita and brachiaria brizantha pasture): At 10%, 20%, 25%, and 30% of replacement; and b) use of multinutricional block based on local agro-industrial by-products as cattle feed supplementation resource. Data from field surveys using semi structured questionnaires and secondary sources were collected and used for the scenario's construction. The economic assessment was carried out in a basis of 10 years' time horizon, taking into consideration economic indicators such as Net Present Value (NPV) and Internal Rate of Return (IRR). Results showed that both strategies can increase productivity and profits at farm level. Silvopastoralism at larger scale gives the highest economic result; however, farmers' decision to implement this strategy may be limited as it requires high investment cost. In the case of multinutricional block, the use in lactating cows (0.346 kg per cow/day) can increase up to 0.40 kg of milk per cow/day during the dry season of the year. We conclude that both strategies could promote more sustainable dairy production in the northern Peruvian Amazon.</p>	
<p><b>Tree rows affected microclimate conditions and thermal comfort indexes for livestock in a Mediterranean agroforestry system</b></p> <p>Currently, climate changes are altering the thermal comfort of animals with negative effects on animal health and feed efficiency while the global demand for animal products is increasing. Thermal stress directly decreases productivity of livestock affecting economic sustainability of extensive livestock systems. The development of agroforestry practices can mitigate the causes of global warming and favors the adaption of grazing animals to extreme events and conditions improving thermal comfort. The aim of this study was to assess the effect of tree presence on microclimate characteristics in a high-tree-density short rotation poplar coppice-based agroforestry system during the summer season within the NEWTON project co-founded by the Tuscany Region (Italy). The field trail was conducted in a coastal plain area close to the city of Pisa (Italy) in the summer 2020. The treatment levels were represented by four positions that were selected according to the distance to the tree rows: westside, eastside, and center of the alley, and open field. Four meteorological stations recorded simultaneously the following data at fifteen-minute intervals: air temperature, relative air humidity, black globe temperature, wind speed and wind direction. Monthly, from June to September, light availability in the investigated positions was recorded with a portable device from 7:00 to 20:00 (CEST). The thermal humidity index, the black globe temperature index and the adjusted thermal humidity index were calculated to determine heat stress. Tree rows affected wind speed and direction, air temperature and black globe temperature. The analysis of thermal stress indexes highlighted significant differences among investigated positions mainly due to radiant heat load and wind speed. The present study shows that beyond to consider the "tree row orientation" factor to exploit light availability for crops, the design of agroforestry systems should consider the evaluation of local wind circulation patterns to obtain effective improvement of thermal stress indexes.</p>	<p>Mantino, Alberto Ritacco, Francesco Annecchini, Francesco Pecchioni, Giovanni Ragolini, Giorgio Mele, Marcello</p>
<p><b>O. Agroforestry - an Essential Pillar of Agroecology</b></p>	
<p><b>Reducing vulnerability and enhancing resilience to climate change through agroforestry: Narratives from smallholder farmers in rural Cameroon</b></p> <p>Climate change poses the greatest threat to smallholder farming systems and smallholder farmers. This is largely due to the limited adaptive capacity of</p>	<p>Temgoua, Lucie Félicité Awazi, Nyong Princely Tchamba Ngankam, Martin</p>

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<p>smallholder farmers confronted with the adversities of climate change. Climate-smart and agroecological farming practices can play a major role in reducing vulnerability and enhancing resilience to climate change. This study was carried out to understand the role played by agroforestry, a climate-smart and agroecological practice, towards reducing vulnerability and enhancing resilience to climate change. Data was collected through focus group discussions (n = 5) and Key informant/expert interviews (n = 30) in five sub-divisions in the northwest region of Cameroon (Bamenda I, Bamenda II, Bamenda III, Santa and Tubah sub-divisions). Findings highlighted the important role played by agroforestry in the provision of environmental benefits like micro-climate buffering, shade, windbreaks, soil erosion control, soil fertility improvement, pollination enhancement and soil water retention. Findings equally highlighted the socio-economic benefits of agroforestry including provision of food, fodder, income, building materials, traditional medicines, fuelwood. These environmental and socio-economic benefits derived from agroforestry systems play a major role in reducing vulnerability and enhancing resilience of smallholder farmers faced with the adverse effects of climate change. Agroforestry therefore needs to be mainstreamed into public policy discourse in order to enable a better valorization of the practice in the present dispensation of climate change.</p>	
<p><b>Design and quantification of ecosystem services from multifunctional agroforestry established for family farming in India</b></p> <p>Multifunctional agroforestry (MFA) have potential to meet 9 out of 17 sustainable development goals which aim to reduce poverty and food insecurity. In order to achieve this goal, a new and unique circular-shaped multifunctional agroforestry model was designed in 2018 comprising of 24 tree species and 8 intercrops. The trees are established in six concentric circles having separate importance viz., high-value timber, timber, plywood, medicinal, fruits and, moringa circles. The total area is also divided into four equal quadrats and different intercrops are raised viz., quadrat I (Flowers), quadrat II (Vegetables), quadrat III (Murraya koeingii), and quadrat IV (Fodders). The border row consists of tree borne oil seeds. Ecosystem services were quantified in MFA. 1. Provisioning services (food, fodder, fruits, timber, medicinal plants):Quantification was done in Kilograms and local market price was used for economic valuation. 2. Regulating services (Carbon sequestration): Non-destructive method was used. Supporting services (Butterflies): Diversity of butterflies was estimated using Pollard walk method. 4. Cultural services: Questionnaire method using Willingness to pay (WTP) was followed. Results revealed the total value of provisioning services from MFA was \$5285.60. The marketable carbon price of MFA was \$206.40. A total of 32 butterflies were recorded in supporting services and the value of cultural services estimated was \$ 0.44 per visit respectively. The study results can be used by policymakers taking into account smallholder farmers' interests and profitability, mainly to achieve the REDD+ initiative, especially in low-income and developing countries.</p>	<p>Arumugam, Keerthika Parthiban, Kallappan Thangamuthu</p>
<p><b>Agroecology for resilient landscapes for the poor in Northern uplands of Viet Nam</b></p> <p>The Northwest is one of its poorest regions of Viet Nam. Local livelihoods mainly originate from agriculture with very few off-farm opportunities. The strongly dissected terrain with high mountains and steep slope limits the ability for local farmers to produce food and achieve food security. The change in global temperature and increase of extreme weather events has worsened the situation. The problem is exacerbated by the overuse of scarce land and the predominance of monocultures, clear cutting of (plantation) forests, favoring high-yield exotic species associated with inappropriate production systems and conservation</p>	<p>Nguyen, Tan Nguyen, Phuong Truong, Can Do, Hoan</p>

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<p>measures. Consequently, local population is facing with accelerating land erosion and scarcity of arable land. The project aims to address the problem of unsustainable livelihood among local poor ethnic minorities in the upland Northwest region of Viet Nam through the umbrella of agroecological approach, with effective participation of relevant stakeholders, particularly the target groups. Gender sensitive agroecological landscapes will be piloted in the project sites to deal with the issues of degraded ecosystem, low land productivity, limited recognition of local knowledge and participation. Market link, post-harvest processing and packaging will be supported and co-benefits will be assessed to boost adoption of agroecological practices. Project results and lessons learned will be documented for scaling up. The project will also specifically build up the capacity of beneficiaries for effective participation in project activities and local decision making process.</p>	
<p><b>Potential benefits of agroforestry systems integrating livestock activities in Guadeloupe</b></p> <p>The value-enhancement of Guadeloupe's forests (71,500 ha, representing 44% of the total land area) is a major challenge for the territory in terms of agroecological transition combined with diverse ecosystem services (ES). In a first step (companion paper) the agroforestry systems in Guadeloupe have been described. One of the conclusions is that complete mixed systems (tree-crop-livestock) should be promoted for the provision of multiple ecosystem services. Owing to different interviews (50 stakeholders and 50 farmers) and 2 focused group discussions, the main interactions existing between systems of production, environment, society, economy and tourism were described. None of the farmers interviewed were familiar with, the term 'ecosystem services'. However, several interviewees had an good intuitive understanding of the ecosystem services concept and used expressions such as 'utility of diverse natural environment, ...' or '... benefits from mother nature ...'. Other interviewees interpreted ES as the responsibility that humans have to preserve nature. We present a figure representing the potential benefits of agroforestry systems integrating livestock activities. The term 'potential benefits' is used because the functions of agro-ecosystems are converted into services only when they are used, consumed or appreciated by humans. This require further biotechnical or economic investigations.</p>	<p>Alexandre, Gisele Cheval, Agathe Diman, Jean-Louis Vinglassalon, Arsene</p>
<p><b>Perceptions, advantages and limits of agroforestry in some parts of Cameroon</b></p> <p>Background: In the last few decades, there have been considerable efforts by the international community to develop strategies that reduce global poverty and hunger. Despite the modest success in reducing food insecurity, there are still around 795 million people worldwide who remain undernourished, the majority of whom are in sub-Saharan Africa. In many of these impoverished communities, agriculture still remains one of the most important sectors in driving economic growth and reducing poverty. For the growing population, with higher food demand and fixed agricultural land, sustainable intensification is proposed as an important strategy to respond to the challenges of low yields, environmental degradation and adaptation to climate change. The adoption of agroforestry technologies is increasingly being promoted as a promising solution. Objective: This study was conducted to determine the perceptions of Cameroonian population and farmers on agroforestry. Methodology: The methodology used was based on a survey to determine their knowledge level of agroforestry, their representation of its advantages and disadvantages, and the reasons that might motivate them whether or not to adopt agroforestry. Participants were randomly selected and received a questionnaire. Data were subjected to a descriptive analysis using SPSS software. Results: The obtained results showed that less than</p>	<p>Djouhou Fowe, Michelle Carole</p>



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<p>50% of the general population had already heard about agroforestry at least once; they have basic knowledge about this concept and its advantages. Farmers had been particularly sensitive to trees' food production function and seemed to value their environmental assets. However, various constraints could affect the possible adoption of agroforestry techniques. Conclusion: Agroforestry has many advantages for farmers. If adopted, it diversifies agricultural products and increases crop yields.</p>	
<p><b>How do shade and auto-shade play a role in pest and disease regulation in cocoa agroforestry systems?</b></p> <p>In agroforestry systems, tree shade cover alters understory microclimate which affects yield, and pest and diseases (P&amp;Ds) development. Important P&amp;Ds of cocoa attack the pods that grow on the trunk and on the lower tree branches underneath the canopy. The development of these P&amp;Ds is thus affected by the microclimate within the cocoa tree resulting from both shade canopy and cocoa self-shading. In this study, we focus on filling the knowledge gap related to how shade canopy and self-shading modify microclimate and contribute to regulate P&amp;Ds. We hypothesize that cocoa trees which receive and/or generate lower shade, will benefit from higher temperatures and lower humidity which is unfavorable for P&amp;Ds development and will be less affected. We also hypothesize that there is a threshold below which the provided shade quantity creates conditions of temperature and humidity that favors the yield while keeping the P&amp;Ds at bay. An exhaustive characterization of 320 cocoa trees distributed over eight cocoa agroforestry systems were conducted over two years in the San Martin Region in Peru. Data on the incidence of three major P&amp;Ds (Moniliosis, American cocoa pod borer, and Black pod), on the pods production, on the morphological characteristics of the trees (total height, canopy height, number and diameter of the trunks) and on the microclimate (temperature and relative humidity) are currently being collected. Shade canopy and cocoa self-shading were characterized using hemispherical photographs, above and below the cocoa tree canopy. Contribution of explicative variables to global incidence of pests and disease will be analyzed using GLMM. Understanding the effect of shade over P&amp;Ds incidence is of key importance in this region as many P&amp;Ds ravage the farmer's crops and threaten their livelihood. Indeed, an appropriate canopy shade and self-shading regulation constitute a relevant cropping practice to reduce negative impact of P&amp;Ds.</p>	<p>Ramos, Marcos J. Allinne, Clémentine Alvarado, Jhoner Rapidel, Bruno Bagny-Beilhe, Leila</p>





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<b>A. Transitioning to Healthy Soils</b>	
<p><b>Improving soil carbon storage by reclaiming industrial degraded lands through short rotation coppice of willow plantations</b></p> <p>The 2 billion trees program is a great opportunity to contribute to the fight against climate change. However, it is possible to further maximize the positive impacts of such a program by combining the planting of trees with the adoption of farming practices that increase the carbon sequestration potential of trees, the reclamation of paper mill sludges, and the restauration of degraded industrial lands. The Carbo-Willow project aims to implement a large-scale GHG capture laboratory on the cover of a landfill site (LS). The concepts that will be explored are: 1) the valorization of LS respecting the principles of both soil conservation and sustainable productions, including a) the application of paper mill sludge and b) the use of alternative farming practices to substitute herbicides for the weed control; 2) the quantification of the potential for both in situ (soil and roots) and ex-situ (exported biomass) CO<sub>2</sub> offsets by a willow plantation on a degraded site; 3) the local valorization of the biomass (production of willow ramial mulch [WRM]) according to a circular economy principle; 4) the development of a CO<sub>2</sub> capture phytotechnology for degraded sites. The 3-years experimental design implies planting 18 ha of willow in 2022, where 8 treatments will be applied to 3 cultivars, repeated 4 times in a randomized complete block design. Mineralization kinetics of the WRM will be studied in respect of the properties of the receiving soil and the WRM's maturity in order to assess the potential of WRM to contribute to the long-term soil carbon sequestration. Atmospheric CO<sub>2</sub> sequestration will be characterized in-situ and ex-situ. Life cycle analysis will quantify resource use and environmental emissions along the chain. The data obtained will be used to support the development of an offset protocol for the mandatory carbon market.</p>	<p>Lalonde, Olivier Lachapelle-T., Xavier Dessureault-Rompré, Jacynthe</p>
<p><b>Characterization of the microbial component in relation to mineral element (N, S, P) use efficiency in temperate agroforestry systems</b></p> <p>Agroforestry is a farming system that includes trees or shrubs on agricultural plots. It has been shown that these associations can increase land equivalent ratio through the establishment of positive interactions between trees and herbaceous plants, such as spatial or temporal niche partition and/or facilitation effect. An instrumented experimental trial located in the North-East of France was installed in 2014 to study above and below-ground ecological interactions between trees and forage crops. This trial includes seven treatments with two alley cropping systems (alder-ryegrass and poplar-clover), two agricultural treatments (ryegrass and clover leys), and three forest treatments (alder, poplar and the mixture of the two species). The growth of poplar in association with N<sub>2</sub>-fixing crops was higher than in the forest mixture and the poplar monoculture suggesting a facilitation effect (Thomas et al., 2021). The heterogeneity of soil physico-chemical properties was characterized to study the temporal evolution of soil microbial variables in relation with below-ground interactions (Clivot et al., 2020). The Ph.D. project that will be presented will focus on other aspects, first concentrating on the dynamic of the abundance and taxonomic diversity of microbial communities over a 7-years period (soil cores sampled since 2014) in relation to soil carbon and nitrogen pools. Secondly, the taxonomic and functional diversity (in relation with their ability to produce phytohormones and mineralize organic pools of nitrogen, sulfur and phosphorus through enzyme activities) of the microbial communities (from</p>	<p>Laprie, Andy Marron, Nicolas Dalle, Erwin Priault, Pierrick Piutti, Séverine</p>

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endophytic to rhizosphere compartment) will be characterized considering both temporal (soil cores since 2014) and spatial (distance to the tree and soil depth) scales in the alder-grass ley treatment. All of this will be done to better understand the below-ground ecological interactions with a focus on the role of microbial communities in the improvement of plant nutrient use efficiency in temperate alley cropping systems.	
<b>Citizen-Science Data Collection for Generation of Evidence on Land Restoration at Scale Using the Regreening Africa App</b> Most people in sub-Saharan Africa are dependent on land for their livelihoods, yet almost half of the land is degraded. Degraded land is unable to meet livelihood needs and often results in increased competition for dwindling resources, which can result in conflict and forced migration. Restoring degraded land is therefore key to ensure food security and in achieving peace and stability. Poor integration of scientific and local farmer knowledge often limits the effectiveness of restoration interventions, and many efforts are not monitored. The Regreening Africa App was co-designed with stakeholders to fill this gap by giving local stakeholders, including farmers, the ability to record and track their own land restoration activities. The app has been developed through the Regreening Africa project, which is a five-year programme funded by the European Union that aims to restore one million hectares and improve the livelihoods of 500,000 smallholder farmers across eight countries Sub-Saharan Africa. Users of the app collect information on where they are conducting tree planting activities and farmer managed natural regeneration, including information on management practices, use of trees, and types of species. The information collected is submitted to a central database and made available to users or projects through a user friendly data reporting system. By using universal icons, the app is accessible to a range of users and the data collected is synthesized and combined with structured data to generate information on critical soil and land health indicators. This information is then shared with the farmers, helping to optimise the design, and tracking of land restoration options. Access to real-time data is allowing structured dialogue and adaptive management by programme implementors and assisting farmers on the ground to effectively scale restoration interventions. This short video will introduce the app and showcase its potential to support landscape restoration.	Bourne, Mieke
<b>Creation of a riparian area with indigenous plants to prevent erosion in Caraquet (New Brunswick, Canada)</b> One of the major constraints affecting New Brunswick (Canada) communities is the impact of climate change. More specifically, in the Acadian peninsula, one of the most significant damages linked to the effects of climate change is coastal erosion. Conventional methods of retaining substrates such as breakwaters and seawalls generally consist in making a mechanical modification of the coastline or in implanting artificial structures. Although effective, those solutions are costly and may not be appropriate depending on the conditions of a site. With the rise of awareness for nature-based solutions to limit the effects of climate change, a long-term project (spread over 5 years) is being conducted with the rural communities of the Acadian peninsula to stabilize the coastline with the plantation of native species on riparian zones. Thus, this study proposes an environmental intervention to the problem of erosion on the Acadian shorelines. This year (second year of the project) was to implement a riparian zone in the municipality of Caraquet (New Brunswick). The method consists in the creation of a natural barrier using a cover of native plants. Moreover, the researcher is using biological substrates capable of promoting the growth of the plants in coastal areas. After	Pelletier, Laurence Haché, Frédéric Tétégan Simon, Marion

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several working groups with the municipality of Caraquet, the plan was created integrating native species, such as <i>Leymus arenarius</i> , <i>Aronia melanocarpa</i> and <i>Cornus sericea</i> . The project, however, is facing several challenges such as the lack of native nurseries and the lack of information regarding a riparian area specific to New Brunswick. Ultimately, the results of this project will have ecological and socio-economic benefits: it will help to restore the coastal biodiversity, will enhance the value of the coastal areas, and will naturally secure the shoreline against erosion, storms and ice scouring.	
<b>Land use change and related impacts on carbon stocks in Ferrasol of southeastern Benin</b> Soil and biomass organic carbon (C) stocks are indicators for monitoring soil and environmental degradation. They are sensitive to land use, which may change rapidly due to demography and pressure on land. The study focused on a highly populated agricultural region in south Benin, the Allada plateau (2140 km <sup>2</sup> ). The objectives were to (i) assess C stocks in 5 carbon pools (aboveground, belowground biomass, necromass, litter and upper 0-30 cm soil layer) according to land uses and to (ii) evaluate their spatial distribution and evolution over 18 years (2000-2018). Field measurements of C stocks in the land uses and classification of Landsat image were performed. InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) model was used to map C stocks in 2000 and 2018. Forests have the highest total C stocks (389 Mg C.ha <sup>-1</sup> ) compared with other land uses (222, 154, 105, 77 Mg C.ha <sup>-1</sup> in plantations, palm groves, crops under plantation and croplands, respectively). The crops under plantation are temporary agroforestry systems based on oil palm. C was mostly stored in the C biomass pool. Plantations, palm groves and built up areas surfaces increased at the expense of forests and crops under plantation. From 2000 to 2018, carbon stocks in the region decreased by 208 Gg C. The most significant values were reported for soil (-179 Gg C) and aboveground biomass (-123 Gg C). Our results confirm that afforestation and limiting deforestation are essential to maintain C stocks. They also highlight the interest in accounting C losses from soil to avoid an underestimation of the C stock dynamics of a rural region.	Houssoukpèvi, Issiakou Alladé Le Maire, Guerric Aholoukpè, Hervé Nonwègnon Sayimi Fassinou, Démayi Jorès Mauryo Rakotondrazafy, Nancy Murielle Amadji, Guillaume Lucien Chapuis-Lardy, Lydie Chevallier, Tiphaine
<b>Contribution d'émondes de <i>Guiera senegalensis</i> (<i>G. senegalensis</i>), <i>Piliostigma reticulatum</i> (<i>P. reticulatum</i>) et <i>Gliricidia sepium</i> (<i>G. sepium</i>) à la productivité des sols sous sorgho dans la zone soudano-sahélienne du Mali</b> Les sols sahéliens sont dans leur ensemble, pauvres en matière organique et en éléments minéraux indispensables à la croissance des végétaux du fait de la rareté de la végétation, de la faible biomasse et de la mauvaise gestion des sources organiques de nutriments végétaux. L'apport des émondes de ligneux permet de restaurer la fertilité des sols. Cette étude a pour objectif d'étudier le modèle de décomposition des émondes de <i>Gliricidia sepium</i> , <i>Guiera senegalensis</i> et <i>Piliostigma reticulatum</i> utilisées en compostage de surface sur les performances agronomiques du sorgho ( <i>Sorghum bicolor</i> ). La technique du litter bag a été utilisée et l'évaluation de treize formules de fertilisation à base d'émondes seules ou en combinaison avec la demi-dose de la fumure minérale vulgarisée a été conduite en plein champ : Sans apport de nutriments; <i>P. reticulatum</i> ; <i>G. senegalensis</i> ; <i>G. sepium</i> ; <i>P. reticulatum</i> + <i>G. senegalensis</i> ; <i>P. reticulatum</i> + <i>G. sepium</i> ; <i>G. senegalensis</i> + <i>G. sepium</i> ; <i>P. reticulatum</i> + <i>G. senegalensis</i> + <i>G. sepium</i> ; <i>P. reticulatum</i> + ½ FMV ; <i>G. senegalensis</i> + ½ FMV ; <i>G. sepium</i> + ½ FMV ; <i>P. reticulatum</i> + <i>G. senegalensis</i> + <i>G. sepium</i> + ½ FMV ; FMV. Les résultats montrent une perte graduelle de poids des émondes dans l'ordre décroissant suivant <i>Gliricidia sepium</i> > <i>Guiera senegalensis</i> > <i>Piliostigma reticulatum</i> avec un	Kouyate, Aliou Badara Dembele, Sidiki Gabriel

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<p>coefficient de décomposition compris entre 0.008 et 0.033. Les paramètres de croissance du sorgho ont été significativement influencés par les traitements. On note que l'ajout de la demi-dose de la fumure minérale vulgarisée aux différentes émondes a permis une amélioration significative du diamètre au collet et le nombre de feuilles du sorgho. Un accroissement de l'humidité gravimétrique est observé avec l'apport des émondes. L'utilisation des émondes peut être une alternative pour la restauration de la fertilité des sols dans la zone de l'étude.</p>	
<p><b>Effect of planting density of <i>Faidherbia albida</i> on soil properties, sorghum and cowpea productivity in the Sudanian zone of Mali</b></p> <p>In the Sahel countries, the issue of land fertility is at the heart of debates on rural development and the future of agriculture. Livestock occupies a preponderant place in production systems, the economy and the social life of households. An integrated approach is needed to resolve both the constraints linked to the soil fertility and low livestock productivity. The effect of planting density of <i>Faidherbia albida</i> on the bio-physico-chemical properties of the soil, the productivity of sorghum and cowpea in the Sudanian zone of Mali is the subject of a study that aims to contribute to improving food security and reducing poverty through the use of agricultural practices resilient to climate change. The trial installed in a device three repetition split-plot experiment includes two factors: (1) Type of cultivation practice at three levels variation: (a) sorghum and cowpea in rotation under <i>Faidherbia albida</i>, (b) sorghum and cowpea in monoculture under <i>Faidherbia albida</i> (c) Pure culture: <i>Faidherbia albida</i>. (2) Plant density of <i>Faidherbia albida</i> under three levels of variation at the rate of 1, 2 and 3 feet per experimental unit of 100 m<sup>2</sup>. The results of the 2020-2021 campaign reveal the weak growth and development of <i>Faidherbia albida</i> in presence of sorghum (average height, 31.96 cm; average diameter at the neck, 0.42 mm; length of the first branching 18.19 cm;) and cowpea (average height, 33.97 cm; average diameter at the neck, 0.47 mm; length of the first branch 18.92 cm;) against average height, 42.72 cm; mean diameter at the neck, 0.54 mm; length of first branch 24.00 cm. We find that this weakness is higher with the high culture from the year the device is installed.</p>	<p>Kone, Souleymane Kouyate, Aliou Badara</p>
<p><b>Harvesting practices and their influence on soil macrofauna in cocoa-based agroforestry systems</b></p> <p>Agroecological approaches require a complete understanding of the agroecosystems by considering complex and countless interactions. Agroforestry systems, that combine at least one ligneous perennial with at least one crop or cattle species, often aim at optimizing ecological and economical interactions among their components. They encompass highly contrasted agroecosystems, from mechanized input-intensive plantations intercropping only two species to family grown, highly diverse and ecologically intensive agroforests. Cocoa-based agroforestry systems have been widely described in the literature for the high taxonomic and functional diversity of the soil biota, especially of larger-sized organisms such as earthworms and macroinvertebrates. However, the interactions between farmer's practices and soil macrofauna are poorly documented. A common practice all over cocoa producing countries consists in piling the harvested pods on a determined area of the plantation floor before opening them. The cocoa beans are extracted and carried out of the plantations, but pod husks remain on the floor. In this study, we compared pod harvesting sites and sites free of pod husks for the diversity of soil macrofauna in the leaf-litter, the 0-10 cm and the 10 – 20 cm soil layers. Based on 60 soil and leaf litter samples, we compared mature (aged 11-25 years) with old (aged &gt; 70 years) cocoa-based agroforestry</p>	<p>Guillonnet, Marie Deheuvels, Olivier Marichal, Raphaël</p>

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plantations in the Dominican Republic. We found that under the cocoa pods, macrofauna density and taxa richness were significantly higher and bulk density was lower. This result is enhanced by the age of the cocoa plantation, as the accumulation of pod husks on a determined harvesting arena tends to be higher over time. The trade-off between a recommendation to spread pod husks over the plantation floor when harvesting cocoa and the current sanitary recommendations for harvesting is discussed.	
<b>Comparison of Soil Morphology Under Tree Windbreaks and Adjacent Fields in the U.S. Great Plains</b> Tree windbreaks or shelterbelts became a common agroforestry practice in the U.S. Great Plains following the severe drought of the 1930's. The U.S. Forest Service created the Prairie States Forestry Project that planted over 300 million trees in six Great Plains states from 1935 to 1942. Following these initial plantings, windbreak practices became well-established across the region with new plantings coordinated through multiple programs and agencies. The objective of this study was to characterize changes in soil profile properties under representative tree windbreaks of four Great Plains states. Two sites in each state were identified with typical tree plantings and adjacent crop fields on the same soil map unit. Sites had a range in mean annual precipitation of 570 to 840 mm, mean annual temperature of 6.2 to 12.8 °C, and tree age from 15 to ~115 years. Soil pits were excavated to 1.25 m within the tree and crop areas and local Natural Resource Conservation Service soil scientists prepared full profile descriptions and classified each profile. Samples collected from pit walls and adjacent auger holes were analyzed for pH, texture, organic carbon (SOC), and nutrient contents. Evidence of previous wind erosion (reduced thickness of surface A horizon) under some windbreaks suggest that their planting was a direct response measure to protect and restore degraded soils. Most windbreak soils had evidence of SOC movement deeper into the profile (darker soil color) while changes in soil structure (type, strength, and size) varied by location and are likely influenced by climate and parent material. Profiles of SOC ( <a href="https://doi.org/10.1007/s10457-019-00425-0">https://doi.org/10.1007/s10457-019-00425-0</a> ) support the morphological observations as subsurface layers (30-125 cm) beneath trees stored on average 7% more SOC stocks than the surface 30 cm. Averaged across all sites, SOC stocks to the 1.25 m depth were 16% greater beneath trees than adjacent fields.	Khaleel, Ala Sauer, Thomas Chendev, Yury
<b>Towards further intensification of push-pull technology with agroforestry</b> One of the sustainable intensifications approaches to improving yields of maize, a major staple and cash crop in eastern Africa, is the push-pull system, a companion cropping system that involves intercropping maize with a forage legume (desmodium), and planting a forage grass (brachiaria) around this intercrop. Push-pull effectively controls stemborer, fall armyworm and striga, while improving soil health and providing fodder. However, the technology is unable to march the current demand for food, firewood and income among smallholder farmers, prompting the need to expand its scope from cereal-based to other important crops and cultivation systems. A participatory needs assessment comprising of 10 focus group discussion with 85 farmers and 25 key informant interviews was held in Kisumu, Siaya and Vihiga in Western Kenya to identify pathways for further intensification of push-pull. Respondents included women and men, farmers, commodity traders, civic leaders, agricultural extension officers, advisory providers and researchers in the region. Respondents identified agroforestry as one of the strategic practices for expanding the usefulness of push-pull system. Farmers grow trees for ecological benefits (soil fertility improvement, erosion control, wind breaks), tree products (fruits, timber, fodder, firewood, medicines,	Buleti, Sylvia Were, Samuel Gichua, Moses Kuyah, Shem



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green manure), income from sale of trees or tree products, cultural benefits or to support other farm enterprises such as bee keeping. Some trees are included in crop fields (e.g. <i>Grevillea robusta</i> ), while others are planted in woodlots (e.g. <i>Eucalyptus</i> ), along soil and water conservation structures (e.g. <i>Calliandra</i> ) or along boundaries ( <i>Makhamia lutea</i> ). Lack of seeds and seedlings, diminishing land, competition with crops, inadequate knowledge regarding trees species, ownership and land tenure, and adaptability limit adoption of agroforestry in western Kenya. Preference and willingness to adopt agroforestry was highly motivated by potential benefits, land availability, training and technical support. There is need to evaluate the performance of push-pull when integrated with woody perennials.	
<b>The assessment of the spatial distribution of soil salinity risk using an index approach, case study: Tadla plain, Morocco</b> Soil salinization is a major environmental issue in irrigated agricultural production. In Morocco, although the irrigation sector is a prominent part of the national economy, it faces problems that impede its sustainable agricultural development. Since the development and the commissioning of the irrigated perimeter, salt-affected agricultural land area has been steadily increasing. For instance, about 16% of irrigated lands in Morocco are affected by secondary salinization. This phenomenon continues to increase and confronts the sustainable development of agriculture. It results from the synergistic effects of climate, bedrock, aggressive natural conditions, and anthropogenic activities. In this context, the present study aims to map soil salinity risk in the irrigated perimeter of the Tadla. To achieve this objective, a modified version of the Soil Salinization Risk Index (mSSRI) approach was adopted. The approach uses physical-natural and socio-environmental factors. Mapping of characteristics such as groundwater electrical conductivity, irrigation water electrical conductivity, soil electrical conductivity, depth water table, aridity index, climate type, slope, texture, geological efficiency, and land cover were carried out to conduct this study. The mSSRI-based approach allows us to identify three sensitive areas of risk: mild, moderate, and severe. The moderate risk class dominates with a coverage of 84.56% of the total area. The area with severe current risk represents only 0.12% of the total irrigated perimeter area of Tadla. The result obtained has shown interest in this approach in order to better mitigate soil salinization risk and reduce its adverse effects on agricultural production.	Chaaou, Abdelwahed Chikhaoui, Mohamed Naimi, Mustapha Kerkour El Miad, Aissa Seif-Ennasr, Marieme
<b>Morphological response of <i>Santalum album</i> with different host species to the saline soil stress</b> <i>Santalum album</i> L., a member of the Santalaceae family, is valued for fragrant oil and has great demand in the international market. However, because of the various regulatory regimes, the species is restricted only in the natural forest areas in the Southern states of India. However, the farmers in North India have recently shown keen interest to cultivate this species on their farmland as a component of agroforestry to boost and sustain their farm income. Sandalwood is an obligate root hemi-parasite that relies on the host plant to extract nutrients and water via haustorial connections. Presently, there is a lack of information on the cultivation and suitable host plants of sandalwood in the saline environment. Keeping the above facts in consideration, the present study was conducted at ICAR-CSSRI, Karnal, Haryana, India, to identify the most suitable host species that can support sandalwood under the salt stress conditions. The ten different hosts, namely, <i>Acacia ampliceps</i> , <i>Azadirachta indica</i> , <i>Citrus aurantium</i> , <i>Casuarina equisetifolia</i> , <i>Dalbergia sissoo</i> , <i>Leucaena leucocephala</i> , <i>Melia dubia</i> , <i>Phyllanthus emblica</i> , <i>Punica granatum</i> , and <i>Syzygium cumini</i> were selected and tested at salinity level EC <sub>iw</sub> 6	Verma, Kamlesh Kumar, Raj Verma, R.C. Kumar, Ashwani Bhardwaj, A.K.



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and in control to identify appropriate host species for sandalwood in the saline environment. Results revealed that on an average salinity stress reduced plant height and collar diameter of sandalwood by 17.25 and 14.36 per cent, respectively. Similarly, in leaf tissues, potassium content decreased by 31.24 per cent, whereas, the sodium content increased by 145.18 per cent. Therefore, based on morphological parameters, the present findings showed that the sandalwood grown with <i>D. sissoo</i> , <i>M. dubia</i> , and <i>A. indica</i> exhibited higher growth potential and better prospects for successful cultivation in the saline environment.	
<b>Estimation of soil carbon stocks and climate resilience potential of Indian Mustard genotypes in Agroforestry system</b> In the present day, the world is facing a serious issue of changing climate like fluctuating temperature extremes, drought, flood, and salinity, in addition to the elevated greenhouse gases. Excessive human interference and unjudged activities have disturbed otherwise normal occurring natural phenomena. The remarkable outcome of this is the deposition of planet-warming greenhouse gases in the troposphere. Agriculture practices are known to be a significant source of greenhouse gases. Thus it has become a critical need to shift our land cultivation practices in a much more organic and efficient way which not only will resist the changing climate crisis, but also help in restoring the natural climate. Agroforestry caters to the need for comprehensive land use management and also solves the CO <sub>2</sub> -induced planet-warming crisis through carbon sequestration in form of biomass accumulation and soil carbon stocks. The presented study was conducted with an objective to estimate the change in soil carbon stocks after two cropping seasons under two agroforestry, Poplar and Eucalyptus, and control (open field) and also assess the climate resilience potential of 10 Indian Mustard genotypes grown as the main crop in these agroforestry systems and also in an open field in an RBD design. During cropping season 2018-2019 and 2019-2020 variation in soil carbon stock was found to be highest in Eucalyptus tree system 30.19-31.48 t/ha followed by Poplar tree system 28.11-29.02 t/ha and lowest in open field 27.10-27.53 t/ha. The performance of Indian mustard genotypes was evaluated based on grain yield and biological yield. Amongst ten Indian mustard genotypes, CS-56 has performed better in all three environments i.e. poplar, eucalyptus, and open field.	Chauhan, Anjana Tewari, Salil
<b>Effect of biochar on sorption and desorption characteristics of cadmium ion on two types of coconut growing soil series</b> Cadmium, a highly toxic trace metal in the environment, accumulates in soil. Consequently, there has been a growing trend in incorporating biochar in agricultural lands to enhance soil health as biochar would reduce the movement of toxicants in the soil. Nevertheless, research on details sorption characteristics has not been much elaborated in this context. A laboratory batch experiments having six replicates were conducted using two soil series; Madampe soil series (M): Sandy loam and Boralu soil series (B): sandy clay loam. Each soil type (3.00 g) was shaken with 40.00 mL of 10 mg L <sup>-1</sup> Cd(II) solution in 0.010 mol L <sup>-1</sup> KNO <sub>3</sub> solution and further inclusion of 100 mg L <sup>-1</sup> of Cu(II), Mn(II) and Zn(II) each ion to represent ionic medium in soil and other competitive ions in soil, respectively. Desorption experiments were conducted with 1.00 g of soil and 20.00 mL of 0.010 mol L <sup>-1</sup> KNO <sub>3</sub> solution. The figure exhibits that the extent of Cd(II) sorption on soil under four soil conditions is higher than that of desorption. Moreover, Cd(II) sorption on B with biochar is lower and the extent of desorption is higher in comparison with other three soil conditions. Higher Cd(II) desorption is an indication of binding on exchangeable sites of soil and biochar and exchange with soil solution. M is marine deposit soil, containing metal oxides mainly, and B is	Nadheesha, Fathima Priyantha, Namal Mohotti, Janaki

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degraded soil with high ion oxides, clay and organic carbon (OC). Cation exchange sites are present in clay, OC and biochar. As Cd(II) has affinity toward cation exchange sites, this study concludes that soil itself reduce the movement of Cd(II) when present in minute levels; however, in the presence of biochar, it is possible to bind Cd(II) on ion exchange sites demonstrating potential in releasing to the soil system.	
<b>Climate-smart bamboo-based Agroforestry strategy using biochar application</b> Adopting a climate-smart agroforestry strategy is crucial for inclusive growth and development of nations which are dependent on rainfed agriculture. Sustainable management of bamboo-based agroforestry can reduce the ill effects of poverty and environmental degradation. An innovative approach in sustainable bamboo plantation management was carried out in a moist semi-arid agro-climatic region of India. Dendrocalamus stocksii is an endemic multipurpose bamboo spp. with steady consumer demand suited for varing agroclimatic zones and even marginal lands. Research trials conducted on biochar application in D. stocksii have yielded promising results in sustaining productivity of bamboo plantations..Biochar has the potential to increase conventional agricultural productivity and mitigate GHG emissions from agricultural soils. The effect of application of combination of inorganic fertilizers with compost and biochar was studied with regard to various biometric parameters of bamboo. 5th inter nodal length , no. of culms per culm and new culm emergence were significantly different from control The results obtained indicate that for sustaining productivity of commercial bamboo plantations inputs in combination with biochar can be a viable option The preliminary results revealed the ratio organic carbon to microbial biomass carbon was highest in NPK treatment (0.18) followed by Biochar and biochar compost.An in-depth ecological analysis was done in soil for finding out the reason for higher productivity including physicochemical properties, microbial biomass carbon and microbial diversity using metagenomic techniques.	P.A, Lubina S, Dr. Sandeep K.S, Dr Anil Kumar Viswanath, Dr. Syam

### B. Transitioning to Better Water Balance and Light Valorization

<b>Water use and physiology of three poplar clones grown at a former municipal and industrial waste dumping site in Wisconsin, USA</b> Water usage, and in general, plant-water relations, are important to understand for tree-based environmental systems, especially those whose success relies on, or is influenced by, water uptake. Poplars (Populus species and their hybrids) are commonly implemented in environmental systems, particularly pollution mitigation systems, due to their elevated water usage, among other factors such as rapid growth and ease of vegetative propagation. However, variations in plant-water relations of poplar genotypes grown in environmental remediation systems are not well-documented. Such information would help practitioners make decisions on which genotypes to select for poplar-based environmental systems. Therefore, we assessed the clonal variation in water use and related physiological parameters among three poplar clones (Populus deltoides × nigra, 'DN34', '9732-11'; P. nigra × P. maximowiczii, 'NM2') at a former municipal and industrial waste dumping site in Manitowoc, Wisconsin. The site is one of sixteen agroforestry phytoremediation buffer systems established with funding from the Great Lakes Restoration Initiative to reduce pollutant transport in the Lake Michigan and Lake Superior watersheds. Sap flow, a proxy for the rate of tree water uptake, was measured using thermal dissipation probes on a 24-hour basis from June–	Rogers, Elizabeth Zalesny Jr., Ronald Pilipovic, Andrej Lin, Chung-Ho Bauer, Edmund Debauche, Brent Vinhal, Ryan Wiese, Adam
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<p>September 2021. Weather (i.e., temperature, humidity, precipitation, wind speed, barometric pressure) and soils data (i.e., volumetric water content, electrical conductivity, temperature, permittivity) were collected onsite during the same period. Additionally, physiological parameters involved in plant-water relations (e.g., leaf water potential, stomatal conductance, leaf area index) were assessed daily from July 13–26, 2021. Integration of sap flow, weather, soils, and physiological data is ongoing. We will present information on water use, its relations to weather and soil parameters, and variations in associated physiological parameters among the three clones. Practitioners, land managers, and others implementing tree-based environmental systems can utilize this information to select poplar clones that will best meet their objectives.</p>	
<p><b>Treatment, recovery and reduction of leachate volumes by filtering willow plantation at the Saint-Nicéphore technical landfill site</b></p> <p>Landfill sites and composting platforms face limitations in terms of the volume of leachate that can be discharged into the environment, since the receiving environments often have too small natural flowrates, and the leachate is only partially treated. Vegetated water treatment solutions based on agroforestry technologies are an innovative response to this problem. To reduce its treatment costs and to protect the receiving environment, the stakeholders of the Saint-Nicéphore landfill site have mandated Ramo to design, implement, operate and evaluate the performance of a vegetated filter system. The system consists of irrigating with intelligent control leachate on a fast-growing shrub plantation, cultivated according to state-of-the-art agroforestry techniques, to treat and reduce leachate volumes. The project, supported by the Ministry of Economy and Innovation, is the first large-scale technological showcase of this technology in North-America. The technical objective of the project is to treat, valorize and reduce an average daily volume of 50 m<sup>3</sup>/d of leachate from May to October and to demonstrate the effectiveness and sustainability of such a system through rigorous experimental monitoring and analysis. The project involves the reforestation of an old landfill cell of 8 ha, as well as the construction of a filtering willow plantation of 2 ha. During the two seasons of operation, several sampling and measurement campaigns were conducted: leachate (11), soil pore water (9), runoff and snowmelt (4), soil (3), leaf biomass (2), woody biomass (2), root profile depth (2) and willow physiology (2). In addition, meteorological, system performance and soil water status data were recorded continuously throughout the experiment. 130,000 shrubs were planted, a total of 8000 m<sup>3</sup> of leachate was recovered and 28 tMS/ha of aboveground woody biomass was produced during the two years of the project. The project has shown the great potential of agroforestry-based solutions for wastewater treatment.</p>	<p>Barbeau, Louis-Clément Lachapelle-T, Xavier</p>
<p><b>Agroforestry for riparian zones: restoring Alto Paranapanema watershed in the Atlantic Forest in Brazil</b></p> <p>The project “Atlantic Agroforestry” aims to restore watersheds in the Atlantic Rain Forest using agroforestry technics. The 100 hectares’ pilot is located in São Paulo State, along Itararé and Paranapanema rivers basins, one of the main catchments responsible for recharging the Guarani aquifer, the most important freshwater reservoir in South America. The region is called “Alto Paranapanema river basin” encompassing three important Environmental Protection Areas and a massive high-quality freshwater reservoir. In this region, 72% of the areas that should be under permanent protection according to Brazilian environmental laws, are currently degraded. Several stakeholder assessments showed that smallholder farmers are concerned about the depletion of water volume in springs waters and</p>	<p>Ziantoni, Valter Noronha, Felipe Saka, Mariana Borges, Mateus Ziantonio, Victor Costa, Paula</p>

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<p>watercourses. Those farmers are prone and willing to adopt regenerative practices in their lands actively. Riparian zones restoration can be conducted using agroforestry logics (stratification, succession, and biodiversity) and techniques; planting short-cycle crops, such as maize and cassava, in the first years, in between native tree species' lines, while trees are still young and small, allowing enough sunlight for the cash crops to grow. NTFP can be included (nuts, seeds, fruits) diversifying markets and engaging farmers even more. The proposed system used in the project consists of tree lines planted every 3 meters with trees spacing around 3 meters and intercropping rows also of 3 meters planted with cash crops. The tree lines alternate lines of seedlings of late secondary species and lines of pioneer species seeds (clusters of species with broken dormancy). Restoring forest at landscape scale enhances the reestablishment of ecological processes and ecosystem services provision. If agroforestry is used to create forest-like agricultural land, wood patches and forest corridors permeate the whole watershed, ultimately avoiding water loss and increasing infiltration and percolation, recharging the water table, and restoring spring waters.</p>	
<p><b>Agroforestry Systems (AFS) to improve the valuation of eco-hydrological services</b>  Rural watersheds have been severely affected by the conversion of natural vegetation to intensive agricultural land use and combination of strategies to restore habitats and promote more sustainable production systems. Nature-Based Solutions (NbS) - which include ecological recovery with Agroforestry Systems (SAF) and Payment for Environmental Services (PES) initiatives - are crucial instruments for mitigating the negative effects of habitat destruction and for engaging social actors in the conservation of ecosystems. In recent years, environmental policies and investments associated with the restoration of the Atlantic Rainforest have managed the landuse of the Paraíba do Sul River Basin (PSRB) to restore its natural resources and PSAs have a prominent role in the scope of the Atlantic Forest Connection Project, an initiative led by the Global Fund for the Environment (GEF), the Brazilian National Government, the São Paulo State Secretariat for Infrastructure and Environment (SIMA / SP) and the São Paulo State Financing Agency (FAPESP). However, despite promoting water production and agroecology, the PES scheme in effect in the Vale do Paraíba region do not index the costs of land use conversion in the evaluation structure considering the natural vulnerability of the Paraíba do Sul River Basin. (BHRPS), as the biophysical conditions increase operating costs. Additionally, the water production potential in each sub-basin is not incorporated, which would allow the ranking of strategic regions for agroforestry management and the sustainability of the system. To contribute to the valuation of water supply services, this proposal highlights the influence of the spatial flow of the water supply service as a service provided from upstream to downstream areas along the water flow direction after meeting local demands. This scenario requires methodologies that combine the the biophysical and hydrological conditions of the environment by a multi-criteria decision analysis based on geographical information system (GIS) and supported by stakeholders. The FAPESP PROJECT, which this proposal is linked, aims to subsidize agroforestry management and native species cultivation on Paraíba Valley and the recovery of the Paraíba do Sul River Watershed in the Southeast corridor of the Atlantic Forest.</p>	<p>Costa De Mendonça, Gislaine  Abdo, Maria Teresa V. N.  Gonçalves, Elaine C. P.  Barcellos, Isabel F.  Carvalho, Renata Egydio De  Pissarra, Teresa Cristina Tarlé</p>
<p><b>Combining event-based analyses of soil moisture measurements with a survey of soil hydraulic properties to assess windbreak influences on water fluxes</b>  The presence of trees can influence the water availability of crops by e.g. introducing competition for water resources, reducing evaporation or by</p>	<p>Hoffmeister, Svenja  Hassler, Sibylle K.  Zehe, Erwin</p>

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<p>supporting water redistribution. We want to assess these influences by studying hydrological interactions in an agroforestry system consisting of an alder windbreak and a blackberry orchard near Stellenbosch, South Africa. We measured soil moisture, soil water potential and precipitation from October 2019 to March 2020. Two locations, directly at a windbreak and within the berry rows outside the windbreak root systems, were equipped with four TDR profile sensors each. Rainfall events (&gt; 5 mm) were identified for comparison with the soil moisture data. Texture analyses of surficial transect soil samples, collected during a field campaign in September 2019, were used to estimate water retention curves from which information on saturated hydraulic conductivity (Ksat), field capacity (FC) and permanent wilting point (PWP) were extracted. The retention curves along the transects comprise similar porosities (0.4 – 0.45), shapes and slopes. Ksat was larger at the windbreak (avg. 116 mm hr<sup>-1</sup>) than in the surrounding field (avg. 101 mm hr<sup>-1</sup>) favouring higher infiltration rates. The PWP differed between the sides of the windbreak. However, the soil moisture observations always exceeded the PWP (0.082 – 0.111 m<sup>3</sup> m<sup>-3</sup>). The FC exhibits a weak northeast to southwest gradient. The soil reactions to the seven identified rainfall events (ranging from 5 mm to 118 mm) differed greatly between events. The soil properties of the samples indicate potentially larger plant water availability between berry rows. In the monitoring data, we tracked more precipitation input into the soil at the berry location as opposed to the windbreak. However, the slightly deeper sensor at the windbreak responded more frequently and more intense to rain events.</p>	
<h3>C. Transitioning to Biodiversity</h3>	
<p><b>Évolution climatique et dégradation des terres dans le domaine du climat soudanien au Bénin</b></p> <p>L'évolution du climat avec ses températures croissantes et la variabilité des précipitations, a un impact sur l'environnement. La présente étude traite de la problématique de la variabilité du climat et ses incidences sur la dégradation des terres. L'étude vise à analyser l'intensité et l'ampleur de l'impact de l'évolution du climat sur les états de surface dans le domaine soudanien au Bénin. La démarche méthodologique est basée sur le calcul des indices d'anomalies climatiques, pluviométriques mensuels d'Angot, d'agressivité climatique à partir des données de précipitations, de température, d'insolation et de l'évapotranspiration potentielle ETP (1971-2020) collectées à la Météo-Bénin. Les données d'occupation des terres (2000-2020) ont permis de déterminer l'indice synthétique d'état de dégradation des terres à partir du calcul des taux moyen annuel d'expansion spatiale et de changement global. Les matrices d'évaluation de l'importance des impacts et de vulnérabilité ont permis d'analyser les résultats. En effet, la période 1971-2020 est marquée par une baisse pluviométrique de 11,47 % (Kandi) et de 6,81 % (Parakou). Le taux de réchauffement climatique est de +0,02 °C/an dans les deux stations. Cette tendance montre qu'en août (3,19 à Kandi) et septembre (2,31 à Parakou), les sols sont soumis à des processus érosifs intenses. La fréquence élevée des années excédentaires (soit 48 % à Kandi et 56 % à Parakou) traduit une forte agressivité (entre 106,91 % et 141,11 % à Kandi et 100,13 % à 177,98 % à Parakou). L'analyse des unités d'occupation des terres entre 2000 et 2020 a montré que les formations naturelles ont régressé (23,12 %) au profit des formations anthropiques qui ont progressé (76,87 %). Le taux de</p>	<p>Adigbegnon, Marcel Sanoussi, Bendjedid Rachad Guelly, Amé Rebecca</p>



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dégradation des terres du domaine soudanien est évalué à 77,14 % en 2020 (soit 6192197 ha). La plantation des espèces à croissance rapide (eucalyptus, teck, acacias), à caractère commercial et l'agriculture biologique sont développées pour restaurer les terres.	
<p><b>Natural recovery of vegetation in a highly anthropized classified forest in Côte d'Ivoire</b></p> <p>Ivorian classified forests have been highly anthropised by agriculture, mainly cocoa farming. The classified forest of Haut-Sassandra (FCHS) has lost 70% of its forest cover to cocoa plantations between 2002 and 2011. The tendency to anthropise classified forests for agriculture raises questions about the future of these forest. In order to guide the government on the approaches to be followed to reconstitute the forest while respecting the aspirations of local populations, permanent plots were installed in the FCHS and were the subject of observations and measurements for 3 years. The objective was to evaluate the capacity of the forest to regenerate naturally following the different agricultural treatments of the infiltrated populations. In each treatment, species richness, growth, mortality and recruitment of trees were recorded for (03) three years. The results showed that the vegetation changes with cessation of some agricultural activities. Species richness increased by 560% in cocoa farms without weeding and with pod harvesting. In cocoa farms without agricultural activities, density increased by 32.04% and basal area by 119.09%. The high rate of recruitment of individuals (411.23%) and average diametral growth (2.13 cm. year<sup>-1</sup>) were obtained in cocoa farms without agricultural activities, while the highest mortality rate (35.55%) was recorded in cocoa farms without weeding with pod harvesting. In sum, tree species could recolonize the FCHS provided that clearing is prohibited in cocoa farms. However, the populations could continue to harvest the pods from the cocoa trees already established in the FCHS.</p>	Kouman, Kouame Jean Marc Barima, Yao Sadaïou Sabas
<p><b>Identifying the role that phytochemicals play in deer browse resistance of northern white cedar</b></p> <p>Northern white cedar (<i>Thuja occidentalis</i> L.) is an important tree species notable for its use in agroforestry windbreak systems. In natural stands, white cedar regeneration difficulties have caused concerns for the long-term sustainability of the species, prompting researchers to investigate factors affecting its regeneration. One such factor is browse pressure from white-tailed deer (<i>Odocoileus virginianus</i> Zimmerman), which can impede white cedar seedling growth and survival, especially when browsing is heavy. While several studies have been conducted to assess the influence of deer browse on white cedar regeneration, the role that plant-produced volatile organic compounds (VOCs), known as phytochemicals, play in influencing deer browse is unknown. This research investigates the relationships between white cedar phytochemical composition and deer browse and seeks to identify the phytochemicals that influence deer browse occurrence. We collected leaf material and seeds of historically browsed and non-browsed trees from a cedar stand in Northern Wisconsin. We used modern bioanalytical and metabolomic approaches to identify and quantify phytochemical compositions of the leaf material and compared the phytochemical profiles among the source populations. Additionally, progeny of the browsed and non-browsed cedar were reared in the greenhouse, outplanted, and monitored via trail cameras to evaluate deer browse occurrence among parent tree sources. Furthermore, the collected cedar leaf material will be subjected to controlled-feeding trials using white-tailed deer to test for differences in cedar leaf material consumption among the source populations.</p>	Vinhal, Ryan Lin, Chung-Ho Zalesny Jr., Ronald D'angelo, Gino



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Significant findings of these ongoing studies will be presented at the conference. Such information on the chemical ecology of northern white cedar and white-tailed deer can not only be used to improve the growth and regeneration of white cedar in natural forest stands, but also to improve the selection of deer browse-resistant white cedar for agroforestry applications.	
<b>Compositional diversity underpins soil organic carbon storage in agroforestry parklands in West African drylands</b> Agroforestry systems (AFS) have the potential to deliver a broad range of ecosystem services including carbon sequestration and biodiversity conservation. Although biodiversity has reportedly enhanced soil organic carbon (SOC) storage in natural ecosystems such as forests, the effect of biodiversity on SOC storage remains largely unexplored in semi-natural ecosystems such as AFS. Here, we elucidated the mechanistic relationship between SOC storage and woody species diversity while accounting for the effects of environmental covariates in agroforestry parklands (AFPs). We collected data on environmental conditions, SOC storage in the top 60 cm and woody species richness, aboveground biomass (AGB), height, diameter, crown area and functional traits across 46 inventory plots established in the semi-arid zone of Northern Benin, West Africa. We used structural equation modeling to test how taxonomic, functional and structural diversity influenced SOC storage directly and indirectly via litter CN ratio and AGB. Among the 11 selected diversity indices, only the community weighted mean of maximum height (CWMMAHX) had a significant direct effect ( $\beta = 0.29$ , $p = 0.017$ ) on SOC storage. There was no significant indirect effect of diversity indices on SOC storage. In comparison, precipitation and fire disturbance consistently had negative direct and total effects on SOC storage. Our results indicate that SOC storage in the AFPs was underpinned by the functional composition of tall trees (representing the selection effects), suggesting that species diversity effect on SOC storage operated through the dominance of highly productive species that enhanced SOC accumulation due probably to greater soil shading, reduced temperature and increased soil moisture. The negative effects of precipitation and fire disturbance on SOC storage show that C losses through heterotrophic respiration and anthropogenic disturbances play a predominant role in controlling SOC sequestration in AFPs. Managing functionally important species will be crucial to support SOC storage in AFPs.	Noulekoun, Florent
<b>Morphological characterization of <i>Allanblackia parviflora</i> in Ghana</b> <i>Allanblackia parviflora</i> A. Chev. is an indigenous tree species which is found in the rain forest zones of Ghana. It is under-utilised fruit tree species that has been targeted for improvement as part of efforts to domesticate high-value multi-purpose trees for fruits and seeds production in Africa. <i>Allanblackia</i> has several benefits which include provision of shade, timber, and medicine, but production of edible oil from the seeds is the economically most important use. The <i>Allanblackia</i> seed oil is currently being developed as a new agri-business in Ghana, Nigeria, Cameroon and Tanzania. This market value would potentially increase livelihood opportunities for farmers and ensure retention of trees on farms for environmental sustainability. However, it still lacks basic information and significant scientific knowledge on phenotypic variability which is crucial for domestication. The objective of the study was to evaluate morphological diversity in <i>A. parviflora</i> fruits/ seeds across four provenances in Ghana, namely, the Wet Evergreen, Moist Evergreen, Moist Semi-deciduous Southeast and Moist Semi-deciduous Northwest. Data were collected from a total of 104 individuals of <i>A. parviflora</i> from February - April, 2021. Ten fruits per tree were collected,	Kyereh, Dennis Hendre, Prasad Muchugi, Alice Kalousová, Marie Lojka, Bohdan

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evaluated and all seeds were characterized for basic morphotypes. <i>A. parviflora</i> was found to be dioecious with male and female flowers. The color of flowers ranges from white/grey to pink/reddish. No ecological differences in number of seeds per fruit, fruit shape and seed weight were observed. However, significant variations in fruit size and shape were observed among individual trees sampled. A positive correlation was observed between fruit size and seed weight ( $R=0.54$ , $P<0.05$ ). Variations could have genetic basis that may be reflected in molecular DNA analysis currently in progress. Selection and cloning of trees with large fruits could lead to higher yield of seeds for oil production.	
<b>Medicinal orchid diversity of Western Himalayas and their conservation</b> Orchids are known for their medicinal values especially in traditional systems of medicine for over 3000 years besides their ornamental importance. Orchid species found in India constitute almost 10 percent of world flora. It is estimated that about 1,300 species belonging to 140 genera are found in the country with Himalayas their main home and others scattered in Eastern and Western Ghats. The diversity is so large that there are large flowered, terrestrial, epiphytic and also saprophytic orchids. Some species in the genera like <i>Arundina</i> , <i>Cymbidium</i> , <i>Coelogyne</i> , <i>Dendrobium</i> , <i>Paphiopedilum</i> , <i>Renanthera</i> and <i>Vanda</i> are almost extinct. The convention of International Trade in Endangered species of Fauna and Flora (CITES), ratified by India, places all species of Orchidaceae, meaning thereby that their trade will be only through export permits. Steps have also been taken to conserve Indian native species by establishing orchidaria, sanctuaries and germplasm conservation centers. Botanical survey of India has established two orchidaria one at Shillong and other at Yercaud to conserve endangered species. The ICAR research complex at Shillong, the Indian Institute of Horticultural Research at Hessaraghatta and the Indian Botanic Garden at Calcutta maintain collections of orchids in their orchidaria. There are 32 sanctuaries and 2 National Parks in Himachal Pradesh, where endangered species of <i>Dactylorhiza</i> , <i>Habenaria</i> , <i>Satyrion</i> , <i>Rhynchostylis</i> , etc. are conserved. Besides, efforts are being made to conserve and propagate orchids in the Botanical Garden of Dr YS Parmar university of Horticulture and Forestry, Nauni, Solan, India. Unless scientific conservation measures are taken along with sustainable utilization, most of the valuable orchid wealth having medicinal, horticultural and easthetic values will be lost. Agroforestry can be one of the possible measures for conservation of these valuable orchids. Most of the orchids are shade tolerant; therefore agroforestry systems can offer a viable option for their cultivation on large scale.	Dutt, Bhupender Sharma, Garima
<b>Nutritive value of <i>Celtis australis</i> in relation to defoliator attack, season and diameter class under mid-hill conditions of north-western Himalayas</b> Tree fodder plays an important role in sustaining the cattle population in mountain ecosystems, the world over. <i>Celtis australis</i> L., is an important agroforestry tree species of the mid-hill mountain ecosystem of north-western Himalaya, which is extensively lopped for its nutritious leafy fodder during the scarcity period. However, off late it is extensively attacked by defoliator beetle ( <i>Diorhabda lusca maulik</i> ), which results in complete defoliation/skeletonization from May-August. Therefore, experiments were carried out in the Department of Silviculture and Agroforestry, Dr. YSP, University of Horticulture and Forestry, Solan (H.P.) during 2019-2021 to study the effect of defoliator attack, diameter classes and seasons on the nutritive value of <i>Celtis australis</i> leaves. The different season under the study were Spring, Summer, Rainy and Winter in three diameter class viz., < 10 cm, 10-20 cm and 20-30 cm. The biomass and phenology were also studied and analyzed with the results to see their impact of defoliator beetle on	Sharma, Vaishali Bhardwaj, D.R. Bishist, Rohit Verma, Subhash Sharma, Prashant Kumar, Dhirender

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tree phenology and growth. The present study revealed that there was variation in nutrient content of undefoliated trees and defoliated tree condition. Similarly, different seasons and diameter depicted profound effect on the nutrient content of leaves. Defoliation of leaves of <i>C. australis</i> resulted in change in phenology and marked decline in the crude protein, neutral detergent fibre and organic matter content. But the level of total ash content, acid insoluble ash content, neutral fibre extract content and total carbohydrate content enhanced. The per cent loss in leaf area and insect population was significantly higher in defoliated tree leaves, whereas the leaf, branch and (leaf +branch) total biomass productivity declined significantly in defoliated trees. However, the re-emergence of new leaves in the defoliated trees and their retention during the Winter season also offers an opportunity for availability green <i>C. australis</i> leaves during the inter season.	
<p><b>Conservation de la biodiversité végétale dans la strate inférieure des agrosystèmes élaeicoles villageois au Cameroun</b></p> <p>La culture du palmier à huile suscite de la controverse. Diversité et richesse spécifiques végétales des agrosystèmes élaeicoles villageois (AEV) sont négligées et mal connues. Ce travail évalue la diversité végétale de la strate inférieure des AEV et les statuts de conservation des espèces. Des inventaires ont été effectués en octobre 2019 et avril 2020, dans 12 AEV couvrant 91 ha et retenus pour leurs superficies, les conditions d'accès et le consentement des propriétaires. La diversité végétale est évaluée en fonction de l'âge, de l'altitude et des pratiques culturales. 156 espèces appartenant à 128 genres et 59 familles ont été recensées. Fabaceae et Asteraceae sont les plus diversifiées avec respectivement 19 espèces pour 15 genres et 15 espèces pour 13 genres. L'âge et l'altitude influencent la diversité floristique (<math>\text{cor}=0,55</math> ; <math>\text{p-value} &lt; 0,01</math> ; <math>\text{cor}=0,68</math> ; <math>\text{p-value}&lt;0,01</math>). Il existe une similarité floristique entre les AEV non élagués et ceux élagués régulièrement (Sorensen (CS)=80%). Les AEV régulièrement et irrégulièrement fertilisés sont floristiquement proches, mais la fertilisation irrégulière est un meilleur compromis pour la diversité floristique (Shannon (S)=<math>1,79\pm0,58</math>). L'élagage irrégulier paraît un meilleur compromis pour la diversité spécifique (S=<math>1,89\pm0,39</math>). Les désherbages irrégulier et régulier sont floristiquement proches CS=54,54%). On note une forte similarité floristique (CS ' 50%) entre les modalités de désherbage ; le désherbage irrégulier étant un meilleur compromis pour la diversité spécifique (S=<math>1,88\pm0,38</math>). Il existe une similitude floristique entre le désherbage manuel et l'absence de désherbage (CS=60%) ; le désherbage manuel est meilleur pour la diversité spécifique (S=<math>1,95\pm0,38</math>). 129 espèces rares sont identifiées dont 49,61% non classées, 45,74% à préoccupation mineure, 2,32% quasi menacées, 1,55% vulnérables et 0,77% en danger. Les AEV abritent une diversité végétale considérablement importante pour la médecine traditionnelle.</p>	Menyene Etoundi, Laurent Florent Ngah, Roméo Pascal Zekeng, Jules Christian Mbolo, Marie Marguerite

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<p><b>A global stocktaking of pollination services in agroforestry systems</b></p> <p>Agroforestry and pollination services are topics of intense interest that go beyond production to synergistically affect the entirety of food and agricultural systems and affect greater biodiversity health and ecosystem services. Much work has been conducted on the status and trends of pollinators but most of those data come from North America and European contexts. Likewise, much research has been conducted on agroforestry, but a global stocktaking of our current academic knowledge of the relationships between pollinators and agroforestry systems has not been conducted. In 2019, FAO conducted a stocktaking to investigate the current knowledge on pollinators and their relationships with agroforestry systems in order to document current knowledge and gaps to provide recommendations for future project focus and policy. This review found that agroforestry systems are diverse and vary greatly across the globe; however, coffee and cacao agroforestry systems were the most researched and it is well established that pollinators' presence is fundamental to both crops. Complexity arises in the differences between managed and wild pollinators and by social and solitary bees within those systems. For instance, honey bee presence may increase with environmental complexity losses, displacing native pollinators which prefer more natural habitats. Different kinds of pollinators can be supported via management regimes: light, shade, and moisture are factors affecting pollinator assemblages and important for the management of agroforestry systems. Additionally, pollinator presence is tied to plant species blooming period and presence of suitable nesting habitat; which can be provided by forest patches or agroforestry. The greatest knowledge gap that remains is that of these relationships in systems other than cocoa and coffee, and specifically in smallholder systems. Future studies should focus on pollinator friendly management of agroforestry systems, the promotion of pollinator-tree mutualisms in agroforestry systems, and the correlation between smallholder agroforestry and pollination services.</p>	<p>Bicksler, Abram Jared Guidotti, Alessandra</p>
<p><b>Contribution of cocoa agroforestry systems to carbon sequestration in Côte d'Ivoire</b></p> <p>The main cause of climate change is increasing concentrations of greenhouse gases in the atmosphere, primarily CO<sub>2</sub>. The purification of the atmosphere of these gases is carried out by several systems, including forests, which absorb more than 25% of CO<sub>2</sub>. In Africa, the Côte d'Ivoire has one of the highest deforestation rates, limiting its capacity to sequester CO<sub>2</sub>. This disappearance of the forest cover is done for the benefit of perennial crops in general and cocoa cultivation in particular; Côte d'Ivoire being the world's largest producer of cocoa with 42% of world production. The association of trees with cocoa trees seems to be an alternative that will make it possible to reconcile agricultural production with CO<sub>2</sub> sequestration. But the complexity of Ivorian cocoa-based agroforestry systems (AFSc) as well as the diversity of actors make it difficult to assess the contribution of AFSc in limiting the harmful effects of climate change. The objective of this study is to assess the potential for carbon sequestration in the various AFSc in Côte d'Ivoire. Specifically, this will involve, on the one hand, making a typology of the different AFSc in each of the cocoa production zones and, on the other hand, determining the rate of carbon sequestered in each of these AFSc. The AFSc typology will be based on data from surveys of cocoa farmers and floristic inventories in different plantations. From these data, variables will be used for a classification of the different systems using statistical tests. The estimation of the carbon rate will involve the calculation of biomass from allometric equations. The</p>	<p>Kouakou, Akoua Tamia Madeleine Konan, Gislain Danmo Barima, Yao Sadaïou Sabas</p>

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resulting biomass will then be converted into carbon. The type of AFSc that contributes the most to mitigating the effects of climate change will be identified and disseminated to cocoa farmers.	
<p><b>Understanding drivers of trees and crop diversity conservation in stallholder farming system of southern Burkina Faso</b></p> <p>In recent decades, socio-economic and rapid environmental changes have significantly affected farming systems and the biodiversity of agroforestry parks. We investigated the pattern of trees and crop diversity dynamic in a context of agricultural land use intensification in a watershed of southern Sudanian of West Africa. A survey was designed with farmers to collect general information on biophysical and socioeconomic conditions and then rank the farms following three categories (young farm, intermediate farm and old farm). Agronomic data and socioeconomic variables were collected with Tree/shrub and crop species inventories on farm following a land use intensification. The generalized linear models (GLM) regressions were run to assess the effects of farms characteristics and management practices of the agrobiodiversity. A total of 20 practices were identified in the Watershed. Crop rotation and buckling are the most common while charring and parcelling are the least known to farm managers. In the sampled fields, 17 crop species were identified in association with woody species. Cereal production, including maize and sorghum, is by far the most common. High statistically significant correlation (<math>R^2=0.9717302</math>, <math>p\text{-value} &lt; 2.2e-16</math>) was identified between plant agrobiodiversity and the woody species richness. A total of 100 woody species belonging to 73 genera and 31 families have been recorded in the fields, the most frequent of which are <i>V. paradoxa</i> (90,32%) and <i>P. biglobosa</i> (59, 14%). We also found that tree diversity decrease from young farm to old farm while altitude and socioeconomic factors affect species composition of parkland. The GLM show that the age of the field, the experience and the farm size significantly negatively influence the diversity of agroforestry parklands. Contrary to expectation cash crop cultivation didn't affect tree diversity in our farming system. Sustainable management of agroforestry system need considerable effort to develop best agroecological practices with smallholder farmer in taking into account both biophysical and socioeconomic conditions of farms.</p>	<p>Cissé, Mohamed Traoré, Salifou</p>
<p><b>Influence of land use on tree species diversity, structure and carbon sequestration in natural and agroforestry systems in Malawi</b></p> <p>With increasing land use change from natural forests to agriculture, policy makers and natural resource managers have been faced with a conundrum to identify appropriate land use compromise to meet both human and ecosystem needs. The present study attempted to understand the influence of land uses on tree species diversity, structure and carbon sequestration in a strictly protected forest reserve (PFR), accessed forest area (AFA) and agroforestry system (AGA) in Central Malawi. Variations in land uses have different effects on tree species diversity, richness, composition, and carbon sequestration capacity. The first hypothesis 'floristic composition, regeneration density and biomass carbon significantly increase with an increasing conservation gradient along land uses' was rejected for floristic composition and regeneration density but was applicable for biomass carbon. The second hypothesis 'horizontal tree structural patterns follow inverse J-shape with an increasing conservation gradient along land uses' did not hold in the protected forest reserve but in the agroforestry and accessed forest. The study confirmed that carbon dioxide equivalent and the associated monetary value increase with increasing conservation gradient along land uses Agroforestry plays important roles in carbon sequestration and conservation of trees, including</p>	<p>Nyirenda, Harrington Chirwa, Paxie Assédé, Eméline</p>



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protected natural species. The economic value of the roles of agroforestry species (monetary value of sequestration) is considered higher than that of the accessed forest area and should be a source of motivation as climate change mitigation advocates. For balanced benefits, there is a need to create some space in the protected forest reserve to enhance regeneration, species richness and sustainability. There is also a need to limit the removal of large trees in the accessed forest area to elongate carbon storage in the trees. Deliberate effort should be promoted to ensure regeneration of the most important species in the agroforestry area to sustain species richness and carbon sequestration.	
<b>Diversifying palm plantations to agroforestry systems</b> In recent years, oil palm kernels are being bought by big companies at a significantly lower price, affecting the economy of local monocrop producers of palm oil ( <i>Elaeis guineensis</i> ) in the southern pacific of Costa Rica. Not only is monocrop production of oil palm representing an economical threat to local producers, it also affects the biological conductivity between forests, creating a harsh landscape, where biodiversity may be scarce and the crops are more susceptible to the attack of diseases. The Osa-Golfito Initiative (INOGO, by its Spanish acronym) developed a diversified oil palm productivity model. This model consists of <i>E. guineensis</i> Jacq. with <i>Cordia megalantha</i> , <i>Theobroma cacao</i> and <i>Musa</i> spp. The present study aims to evaluate the productive, environmental and economic potential of the oil palm agroforestry system established, in search of a more sustainable productivity model for the local community. Income per crop will be estimated throughout the years by recounting the productivity of each crop. To evaluate a potential change of soil properties throughout the years, a baseline of the chemical and physical properties of the soil were determined. At three years since its establishment, the canopy structure presents a shade percentage below 12% and with crops that are susceptible to the amount of shade received, this percentage is considered low for the first years. Nevertheless, for instance, the total height and kernel weight of the oil palm was found to be greater in the diversified plots than in monocrop plots. Stem rot affectation in oil palm was found higher in monocrop plots than in diversified plots (9,9%,-7,4% respectively). In diversified productive systems, management and maintenance seems to be a key factor in guaranteeing a good crop development. An adequate appropriation from the producer increases the possibility to generate quality products, therefore generating better income.	Salazar-Díaz, Ricardo
<b>Towards Meeting Sustainable Biodiversity: Evidence from Cocoa Agroforestry System in Ghana</b> Cocoa agroforestry system is regarded as a multiple-win practice as it can protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss for a sustainable future. The primary objective of the paper is to examine cocoa agroforestry as an option in meeting sustainable biodiversity. This paper aims at bridging the knowledge gap by providing empirical by seeking to evaluate conservation value of cocoa and forest interaction as well as showing how cocoa agroforestry system can contribute to the development of rural and community forestry to achieve the sustainable development in Ghana. Simple random sampling technique was used to select four cocoa growing communities and 400 cocoa agroforestry farmers in the Western Region of Ghana were selected. Both descriptive and inferential analyses were used to analyze the data. About 95% of the respondents indicated that cocoa agroforestry places emphasis on the potential of smallholder tree based systems to expand regional	Nunoo, Isaac Boakye, Twumasi-Ankra Angella, Twumasi-Ankra Benedicta Nsiah, Frimpong Enoch Brefo, Mensah3



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forest resources and, produce forest products and services as well as representing a major contribution to local livelihoods for rural communities. Further analysis showed that cocoa agroforestry has multiple benefits in the form of both products and services: they yield food, fuelwood, fodder, timber and medicines. Over 25 species of timber trees were retained on the farm. Farmers indicated that retaining shade trees on cocoa farms improved yield, create a micro climatic environment for sustainable yield over time. In conclusion from the study, cocoa agroforestry system emerges as a promising land use option to meet the biodiversity and Sustainable Development Goals. Policies to promote this integrated landscape approach, that incorporates agroforestry concepts and practices, to overcome barriers and accelerate action for achieving biodiversity goals associated targets need being promoted.	
<b>Woody landscape elements for farmland biodiversity</b> Maintaining farmland biodiversity is an argument that is often put forward for promoting agroforestry systems. Here we summarize the outcome of 10 years of research on the role of woody elements in German and Swiss agricultural landscapes for various species groups (biodiversity conservation) and for the provision of ecosystem services such as pollination and pest predation. We found that the connectedness of woody habitats was more important than their actual amount. Species richness of birds, spiders and beetles, and the abundance of some bird species decreased significantly in isolated traditional fruit orchards. Isolation was particularly detrimental for natural pest regulators, birds and spiders and affected their interactions with herbivorous insects (1, 2). Also, the pollination of fruit trees was negatively affected (3). Seasonal pollen records revealed that in early spring, bees and natural enemies (ladybeetles, lacewings) rely particularly on pollen collected from trees and shrubs (4), which is the pre-requisite for building up their populations, so that later in the season pollination and pest control services in agricultural crops can be provided. Agroforestry systems can thus contribute to maintain biodiversity and ecosystem service provision in agricultural crops if they are well connected to forest edges and to hedgerows and – ideally – if they contain a certain share of pollen and nectar providing tree or shrub species. (1) Bailey D. et al. Journal of Applied Ecology 47, 1003 – 1013; (2) Schüepp C. et al. Biological Control 71, 56 – 64; (3) Schüepp C. et al. Proceedings of the Royal Society B 281: 20132667; (4) Bertrand C. et al. Journal of Applied Ecology 56(11), 2431 – 2442.	Herzog, Felix Entling, Martin
<b>Is there an evidence base to assess the alleged benefits of agroforestry?</b> Agroforestry is often seen as a panacea that offers multiple environmental, economic, and social benefits. The validity of generalized statements on agroforestry outcomes however is doubtful since the evidence base is unclear. Systematic reviews and meta-analyses that address specific outcomes of individual agroforestry practices at different sites exist on this topic. But the overall picture of available scientific evidence on agroforestry outcomes remains opaque due to the wide diversity of existing agroforestry practices, outcome indicators, and geographical locations. For this study, we created an evidence review map for clarifying whether and in which areas the research landscape allows conclusions to draw on potential benefits or drawbacks of agroforestry compared to other land uses. Based on a systematic literature search and screening from 2,164 articles, a final set of 64 systematic review articles were identified that summarize ecological, economic, or social outcomes of at least one agroforestry practice compared to a control. The thematic and geographical coverage of the articles is mapped to identify density and research gaps in the evidence base. Moreover, the	Koethke, Margret Ahimbisibwe, Vianny Lippe, Melvin

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included articles were critically appraised. The results of the evidence review map discloses an extensive evidence base for environmental outcomes on climate change, water, biodiversity, soil and pest/ disease control as well as for productivity aspects of individual agrisilvicultural practices, as well as for agroforestry systems on an aggregated level. Research gaps were, however, detected for individual silvopastoral and agrosilvopastoral practices. Major research gaps are identified on social outcomes of all agroforestry types. Moreover, most studies have a restricted geographical coverage. Global coverage for individual agroforestry practices is only available for studies on climate change outcomes. The results of the evidence mapping highlight further research needs, but also urge for caution in making generalized statements about the benefits of agroforestry.	
<b>Climate change impact on species distribution modelling in relation to phenotypic diversity of an agroforestry species: <i>Afzelia africana</i> Sm. in Benin</b> <i>Afzelia africana</i> is a selectively harvested agroforestry species reported in Benin and internationally classified as vulnerable species. For a sustainable use of this resource, we evaluated (i) the variation in phenotypic diversity between different populations of <i>Afzelia africana</i> in relation to climatic factors and (ii) the impact of climate change on favorable habitats distribution (iii) how phenotypic diversity is affected by climate change effect on favorable habitat distribution. A total of 100 individuals tree from 13 populations were sampled through the three climatic zones. Morphological traits of fruits and seeds were assessed among the studied populations and the areas of homogeneous diversity were related to climatic variables. The SDM was used to assess the effect of climate change on the distribution of the species in the present and the future. A clustering test was performed on the occurrence points of the species. The results of the regrouping were subjected to the climate niche modeling. The measured morphological traits of fruits and seeds were significantly different among the different populations. Three classes of individuals were revealed by hierarchical classification analysis according to the phenotypic diversity variation. The individuals of class 3 constitute elite individuals class and are located in in the Guinean zone which reveals moderately favorable habitats for the species in the future. Climate change is lowering the phenotypic diversity of the species and favoring the development of unfavorable habitats in the future. Bioclimatic variables have thus been identified as potential traits interacting with phenotypic diversity. These combined variations in phenotypic diversity and climate change effect on favorable habitat distribution are valuable information to guide the sustainable management and conservation of populations of <i>Afzelia africana</i> in different climatic zones and habitat types in Benin.	Houehanou, Thierry Dèhouégnon Adjacou, Dowo Michée Gouwakinnou, Gérard Nounagnon Yaoitcha, Alain S.
<b>Study of the mycorrhizal interaction between cocoa and <i>Terminalia superba</i>, <i>Irvingia gabonensis</i>, <i>Milicia excelsa</i>, <i>Ceiba pentandra</i> and <i>Persea americana</i>, in three agro-ecological zones in Côte d'Ivoire</b> This study determines the mycorrhizal interaction between cocoa trees and five companion trees used in agroforestry systems in Côte d'Ivoire. These are <i>Terminalia superba</i> , <i>Irvingia gabonensis</i> , <i>Milicia excelsa</i> , <i>Ceiba pentandra</i> and <i>Persea americana</i> . In order to do this, in three different agro-ecological zones, soil samples were taken from the rhizosphere (0-20 cm) of these trees as well as from the rhizosphere of three neighbouring cocoa trees in different directions. The diversity of arbuscular mycorrhizal fungi (AMF) communities associated with companion trees and neighbouring cocoa trees was determined by the wet sieving method before and after trap culture and the results compared. Mycorrhization	Amani, Yves Frederic Cyriak Mbo, Kacou Alban Antoine Kone, Daouda Kouame, Christophe

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<p>frequencies, intensities and AMF abundance were also determined on both sides. The results suggest strong interaction between companion trees and cocoa trees in all agroecological zones. The mycorrhization rates of companion trees did not vary between agro-ecological zones. Ceiba pentandra showed the strongest interactions with cocoa, and obtained the highest mycorrhization rates, corresponding to 100% frequency and respectively intensity and spore density; 55.72% and 14.32 spores/g soil. On the other hand, the lowest mycorrhization rates were observed in Terminalia superba, with respectively frequencies, intensity and spore density of 89.97%; 9.64; 5.50 spores/g soil. Despite the fact that the three areas had contrasting soils, the genera Glomus (76.26%) and Acaulospora (14.98%) were the most involved in mycorrhizal symbiosis between cocoa and companion trees.</p>	
<p><b>Distribution and cultural identity of sacred groves in Togo (West Africa)</b>  Sacred groves are recognized as real heritage of biodiversity conservation for countries with no large forest areas. However, several threats, particularly human activities, lead to the disappearance of these forest islets. This study aims to highlight at the national level, the distribution, phytogeographical and cultural characteristics of the sacred groves based on inventories, systematic mapping. The results reveal that Togo has more than 780 sacred groves which cover 3,627.68 ha. The majority of the sacred groves are of small size, i.e. 78.83% of sacred groves are less than 5ha. The most dominant sacred groves are woodlands (1974.3ha), dense forests (882.52 ha) and Tree savannas (640.23 ha). Most of the sacred groves are on the low lands or plains (75%) against 25% sacred groves on highlands or mountain chains. In terms of cultural distribution, Adja-Ewé ethnic group located in the south of the country hosts the largest number of sacred groves (248 sacred groves or a proportion of 31.79%, 1,377.53 ha). Many deities and vocations were associated to sacred groves. Therefore, we can distinguish ceremonial and prayer sacred groves (80.86%), voodoo and conservation sacred groves (12.46%), cemetery or burial sacred groves (3.11%), residence or retreat sacred groves (2.52%), secret meetings, festivities or celebrations sacred groves (1.03%). With these diversity of socio-cultural functions and conservation roles of the sacred groves, it is urgent to consider them in the framework of REDD+ strategies implementation in Togo.</p>	<p>Hounkpati, Kossi  Adjonou, Kossi  Kokou, Kouami</p>
<p><b>The contribution of Ketak to rural livelihoods and tree diversity conservation in Sumbawa, Indonesia</b>  The high demand for corn products in the Indonesian market is the cause of the high land conversion from the smallholder agroforestry systems to corn agricultural land in the Semongkat Watershed, Sumbawa District. This has threatened the existence of the candlenut agroforestry system - as the main source of income for the community - as well as the natural forest located in the middle and upstream part of the watershed. Ketak (Lygodium circinnatum) which grows naturally in the candlenut agroforestry system and natural forest is also threatened. Ketak is usually used as the raw material for traditional woven handicrafts and is highly demanded by the local and international market. However, the condition of this species in their natural habitat is unmaintained and tends to be an underutilized species. The optimizing potency of this species is expected to positively impact the rural livelihood and environmental condition in Sumbawa. The data of this study were collected during the Kanoppi phase-2 project through inventory survey, FGD, key informant interviews, and farmer training. The result shows that many Ketak were found in the candlenut agroforestry system with a density of clumps per hectare of 126.3 clumps/ha.</p>	<p>Sabastian, Gerhard Eli  Susila, I Wayan Widhiana  Fambayun, Rizki Ary</p>

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Based on managing Ketak using silvicultural practices (vines thinning and providing climbing trees) in the candlenut agroforestry system, the productivity of Ketak's vines can reach 757.8 vines per hectare with expecting to deliver a positive net present value to the farmers and resulting in the Benefit-Cost Ratio was 1.95. Furthermore, the presence of climbing trees is highly required in managing Ketak to keep it growing well. Farmers are required to keep the tree diversity in their farms and practice silvicultural management to optimize the contribution of Ketak to their livelihood as well as to sustain the management of smallholder candlenut agroforestry system and nourishing natural forest in Sumbawa.	
<h3>D. Transitioning to a Viable Climate</h3> 	
<b>Agroforestry and ToF (Trees Outside Forests ) Potential in supporting India's Roadmap towards Carbon Neutral Economy by 2070</b> India's Commitments during UNFCCC CoP 26 to deal with Climate Change related challenges, through promotion of Agroforestry and Trees Outside Forests have to play a pivotal role in meeting commitments related to; Reduction of at least one billion tonnes of total projected emissions between now and 2030, Reduction of the country's carbon intensity to less than 45%, Achieving net-zero emissions target by 2070. Agroforestry also enhances provision of ecosystem services, especially Carbon sequestration, and economic opportunities. Haryana State has demonstrated and led the example, that, how a forest and natural resources scarce and deficient State with only about 3.5 % area under Forests and more than 80 % area under Agriculture can support the Nation's Food Security and Wood Security. Availability of high productivity and short rotation seedlings of Eucalyptus and Poplar seedlings have played a pivotal role in making Yamunanagar District as Plywood Capital of the Country. Clonal Eucalyptus and Poplar seedlings have short harvesting period of 4-6 years. Farmers income is supplemented through farmwood wood based production along with agricultural crops. There are about 350 plywood units in the State. Yamunanagar Wood Market supports more than 50 % of the India's Plywood Production. Appropriate Policy measures, supported by technology transfer, diversification of wood based products, ensuring appropriate returns to wood grower for encouraging adoption of agroforestry, setting up of industries at strategic locations for balanced agroforestry based industrial development to absorb the available wood, continuous market research are needed. Haryana Model is one of the success story, widely acknowledged globally. Agroclimatic regions based appropriate agroforestry and ToFs models need to be promoted to realize the potential in different States across the Country. This will facilitate in harnessing the Country level potential of Agroforestry and TOFs in shaping "Climate Action" as per India's commitments for Carbon Neutral Economy by 2070.	Saxena, Vivek
<b>Smallholder coffee producing farmers perception and their adaptation strategies of climate change in South-Eastern Ethiopia</b> Recent studies suggest that farmers' perceptions of climate change influence how they adapt to climate change. Therefore, the overall objective of this study was to assess the perceptions and adaptation strategies of smallholding coffee producing farmers of climate change and variability along agroecological gradients in Sidama National Regional State, Ethiopia. The data were collected from the randomly selected 351 respondents. This study performed a Mann-Kendall test to ascertain climate trends. Severity Index (SI) and Weighted Average Index (WAI) were	Jawo, Tariku Olana Lojka, Bohdan

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<p>estimated to measure farmers' perceptions of climate change and rank identified adaptation strategies, respectively. Multiple regression analysis was also conducted to identify determinants of perception on climate change and their adaptation strategies. Farmers' perceptions of an increasing temperature concurred with meteorological data analysis but not with the rainfall trends. Mann Kendall test results revealed that there was a slightly increasing trend in annual rainfall in the low (<math>p = 0.05</math>), mid (<math>p = 0.006</math>) and high (<math>p = 0.02</math>) lands. The study revealed that the highest SI recorded for an increased temperature, followed by unknown when the rainfall begins, increased number of hot days, the rainy season begins later than usual and decreased rainfall as farmers perception of climate change and variability. Regarding climate change adaptation strategies, a significant proportion of the respondents' practised agroforestry (WAI = 3.30) followed by application of compost (WAI = 3.12), soil conservation (WAI = 2.81), change farming calendar (WAI = 2.46) and crop diversification (WAI = 2.38). The adaptation strategies implemented by the farmers help to adapt to climate change but requires designing effective adaptation strategies. Therefore, enhancing farmers' adaptation to climate change requires developing effective adaptation strategies and conquering challenges associated with adaptation practices to avert climate change's effect and pursue climate-resilient coffee production in the study region.</p>	
<p><b>Pigeon pea: a multipurpose crop with great potential for carbon sequestration in Africa and South Asia</b></p> <p>Sustainable intensification is one of the options recommended for increasing carbon sequestration for the dual purpose of improving crop productivity and mitigating climate change. Yet many questions remain, such as which species give the greatest soil and aboveground carbon benefits. The CGIAR Research Program on Grain Legumes and Dryland Cereals has identified pigeon pea (<i>Cajanus cajan</i>, L.) as one of the priority crops capable of transforming underperforming agriculture to become resilient, productive and profitable. Despite the large body of literature on pigeon pea, its contribution to carbon sequestration in agroforestry has not yet been synthesized. We scanned publications to determine the role of pigeon pea in carbon sequestration in Africa and South Asia. Carbon in post-harvest (aboveground) residues from pigeon pea was <math>2.21 \pm 0.38</math> Mg/ha in Africa and <math>2.75 \pm 0.34</math> Mg/ha in South Asia. Using average root-to-shoot ratio (RS) for pigeon pea (RS=0.21), and assuming 47% carbon fraction in dry matter and 65% carbon in rhizodeposition, total carbon potentially available for addition to the soil ranged from <math>1.21 \pm 0.44</math> Mg/ha when residues are removed to <math>2.98 \pm 0.51</math> Mg/ha when residues are retained in Africa, and from <math>1.50 \pm 0.54</math> Mg/ha when residues are removed to <math>3.70 \pm 0.46</math> Mg/ha when residues are retained in South Asia. Absolute soil organic carbon concentration (SOC) on farms with pigeon pea was <math>1.68 \pm 0.19\%</math>. The effect of pigeon pea on SOC was positive and significant (lnRR: 0.299, 95% CI= [0.02, 0.84]). On average, SOC in farming systems with pigeon pea was 35% higher at the end of experiment relative to values at the start of experiment. High biomass production and SOC increase under pigeon pea shows its potential to build resilience when integrated into current smallholder farms. We discuss the challenges and opportunities for integrating perennial grain legumes in tree-based cropping systems, including recommendation for future research priorities.</p>	<p>Kuyah, Shem Bayala, Jules Dimobe, Kangbeni Hughes, Karl Jonsson, Mattias Muoni, Tarirai Shalander, Kumar Dahlin, Sigrun Sileshi, Weldesemayat Öborn, Ingrid</p>

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<p><b>Above ground and below ground biomass production and carbon storage potential of different agroforestry systems in low hill zone of North Western Himalaya</b></p> <p>Agroforestry is an ecologically and environmentally sustainable land use system which offers great promise to store and sequester carbon. The objectives of this study was to identify and examine the above ground (AG) and belowground (BG) biomass production and carbon storage potential of existing agroforestry system in low hills of North western himalaya. The present investigation was carried out in Nalagarh region of Himachal Pradesh, India at two elevation zone viz. Zone I (&lt; 600 m amsl), and Zone II (600-1200 m amsl). Six agroforestry systems practiced by the farmers of the study area in zone I and II were Agri-silviculture (AS), Agri-silvi-horticulture (ASH), Agri-horticulture (AH), Agri-silvi-pasture (ASP), Silvi-pasture (SP) and Pastoral-silviculture (PS), respectively. The biomass and carbon storage of different agroforestry systems showed a significant increase in value from zone I to zone II. The results of the study revealed that a significant variation was observed among all the agroforestry systems, the maximum biomass production (AG 29.57 t ha<sup>-1</sup>, BG 11.32 t ha<sup>-1</sup> and Total biomass 39.84 t ha<sup>-1</sup>) and carbon storage potential (AG 13.30 t ha<sup>-1</sup>, BG 5.09 t ha<sup>-1</sup> and total carbon stock 15.04 t ha<sup>-1</sup>) was recorded in ASH followed by SP, AS, AH and ASP respectively. However, pastoral-silviculture (PS) has the minimum biomass (AG 11.69 t ha<sup>-1</sup>, BG 3.77 t ha<sup>-1</sup> and total biomass 15.04 t ha<sup>-1</sup>) and carbon stock (AG 5.25 t ha<sup>-1</sup>, BG 1.69 t ha<sup>-1</sup> and total carbon stock 6.76 t ha<sup>-1</sup>), respectively. From this study it can be concluded that agri-silvi-horticulture system is more viable option and has more potential to store carbon in comparison to other existing agroforestry systems of the study area to harness the environmental services of the system in current scenario.</p>	<p>Singh, Gurwinder Gupta, B. Kumar, Dhirender Sharma, Harish Bhardwaj, D.R. Thakur, C.L.</p>
<p><b>Agroforestry based solutions for Environmental Security</b></p> <p>In the current scenario the most challenging aim before all nations is to evolve viable strategies to reduce atmospheric CO<sub>2</sub>. There is an urgent need to adopt suitable climate-smart technologies to meet the objectives of minimizing greenhouse gas emissions and develop a strong path to achieve the targets set aside by different binding treaties of the world against climate change. Agroforestry can be one of the such viable solutions through which agricultural ecosystems can be further improved to ensure environmental and biodiversity restoration, realization of ecological services including climate change mitigation and adaptation mechanisms for improved and sustained livelihoods. The adoption of suitable agroforestry technology based on specific agro-ecological regions is very important to harness the full potential of agroforestry for its ecosystem services. These benefits can be achieved at an early stage compared to monoculture plantations or forests based on utilization of multilayer strata. The studies conducted under the All India Coordinated Research Project on Agroforestry have identified suitable agroforestry technologies and their environmental benefits. The present article attempts to highlight the potential of agroforestry interventions from the viewpoint of environmental security and adaptation to changing climate scenarios through carbon sequestration.</p>	<p>Handa, A.K. Arunachalam, A. Sirohi, Chhavi Ram, Asha Ramanan, Suresh Kumar, Naresh</p>
<p><b>Building a global carbon database to characterize agroforestry as a natural climate solution</b></p> <p>There is growing interest in agroforestry as a climate solution, given its potential to store additional carbon in agricultural landscapes, while also enhancing livelihoods and biodiversity. However, substantial uncertainty remains around how much carbon can be captured, and how that varies by location and by</p>	<p>Cook-Patton, Susan Biswas, Tanushree Cardinael, Remi Culbertson, Katherine De Stefano, Andrea Garcia, Edenise</p>



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<p>practice. One of the central challenges is the sheer diversity of agroforestry practices employed across the globe. Species identity, planting density, and management practices, as well as many other factors, will influence the overall climate mitigation potential of an individual agroforestry system. Although recent reviews have begun to compile carbon sequestration rates and stocks within agroforestry systems, the current evidence base is not fully comprehensive. Individual reviews have examined only a subset of the existing literature and typically partition agroforestry systems into coarse categories that do not reflect the diversity of actual on-the-ground practices. As individuals, corporations, and governments decide whether and how to deploy agroforestry as a climate solution during this climate critical decade, there is a strong need for a readily available and comprehensive dataset to better predict climate outcomes across diverse agroforestry systems. We have therefore conducted a systematic review of published studies to find empirical estimates of carbon sequestration rates and stocks in agroforestry systems. After reviewing over 18,000 papers, we have identified 800 or more papers that appear to have the necessary information. We are compiling this information into a consistent data structure to create a publicly available dataset that can help to accelerate our scientific understanding of the climate mitigation potential of agroforestry and facilitate the incorporation of agroforestry into climate goals. Although agroforestry offers high potential as a climate solution, delivering on that promise requires a more precise understanding of how much carbon can be captured, based on the best available data.</p>	<p>Jacobson, Michael Neupane, Kripa Rosenstock, Todd Sprenkle-Hyppolite, Starry Suber, Marta Surdoval, Alison Terasaki, Drew Thapa, Bhuwan Valverde, Yesenia Wood, Stephen Yeo, Sam Zarate, Alina</p>
<p><b>Evaluation of experimental agroforestry systems for their carbon sequestration and soil enrichment potential in mid-hills of north-western Himalayas</b></p> <p>Agroforestry systems (AFSs) are not specifically intended for carbon sequestration (CS), however, several recent studies demonstrated that AFSs can play a significant role in C storage both in both biomass as well as in soil. Thus, the present investigation compared six experimental AFS, namely fruit, fodder tree, bamboo, melia, poplar, and silvi-pasture systems to conventional systems prevalent in the mid-hills, such as sole cropping, agri-silvi-horticulture, and agri-silviculture systems, for CS and soil enrichment potential. The results reveal that the vegetation biomass was higher among all the agroforestry systems as compared to control systems and maximum biomass was evident in poplar-AFS (130.87 Mg ha<sup>-1</sup>), which was more than sixteen times than that of pure agriculture. Subsequently, the maximum vegetation C density (65.44 Mg ha<sup>-1</sup>), leaf litter C density (0.66 Mg ha<sup>-1</sup>) and total C density (173.91 Mg ha<sup>-1</sup>) was recorded in poplar-AFS, whereas soil C density (113.71 Mg ha<sup>-1</sup>) in silvi-pasture system. Additionally, the rate of CS and CO<sub>2</sub> mitigation in the soil sphere was found to be highest in bamboo-AFS (1.81 &amp; 6.65 Mgha-1yr<sup>-1</sup>) whereas, in vegetation (3.72 &amp; 13.67 Mg ha-1yr<sup>-1</sup>) and total (5.26 &amp; 19.30 Mg ha-1yr<sup>-1</sup>) were in poplar-AFS and melia-AFS, respectively. All the physico-chemical properties investigated, total microbial count and soil quality index improved under the AFS vis-à-vis sole cropping systems. The bamboo- and fruit-AFSs exhibited the highest outcomes in terms of soil enrichment potential. As, bamboo-AFS had the highest available nitrogen (301.47 kg ha<sup>-1</sup>), potassium (245.69 kg ha<sup>-1</sup>), exchangeable calcium (1496.53 mg.kg<sup>-1</sup>) and sulphur (34.07 kg ha<sup>-1</sup>). However, fruit-AFS markedly dominated other AFSs in terms of all major micronutrients (Cu, Fe, Mn and Zn). Overall, experimental and natural agroforestry systems outperform monoculture cropping systems in terms of both CS as well as soil enrichment potential.</p>	<p>Verma, Tarun Bhardwaj, D.R. Thakur, C.L. Sharma, Uday Sharma, Prashant Kumar, Dhirender</p>

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<p><b>Resilience of agro-systems by combining water and soil conservation techniques with Agroforestry</b></p> <p>In the context of the revitalization of the Great Green Wall (GGW), the potential of combining agroforestry with Soil and Water Conservation techniques (SWC) can accelerate the rehabilitation and resilience of Sahelian agrosystems. Indeed, if woody cover improves water and soil conservation, SWC practice enables tree regeneration. Thus, the research questions raised by the JEAI-PRESAF project are: how can the innovations of Farmer Managed Natural Regeneration (FMNR) and soil and water conservation (SWC) fit into an agroforestry space? what is the level of sustainability of these types of associations? This intensification practice can only be sustainable and up-scaling if the bottleneck limiting its adoption is known. Compared to the unique practice of FMNR or SWC, and through their augmentative effects, the rehabilitation of agrosystems is accelerated and the capacity of the ecosystem to provide goods and services is increased. Our approach is based on a diagnosis of past and present socio-economic, agronomic and environmental contexts and performance through the study of two variants of agroforestry space associated with SWC in Niger. In order to provide pathways for adjusting and optimizing agroforestry practices associated with SWC, we are investigating two sites in Niger: 1) a multi-species park resulting from FMNR combined with zāi in Maradi region, and 2) a <i>Piliostigma reticulatum</i> park combined with half-moons in Tahoua region. In order to perpetuate the actions of this project, we aim to set up a scientific observatory "Societies-Environments" as a tool to support land management with the purpose of predicting the long-term innovations impact on the matter cycle (e.g., carbon, water, and nutrients) in order to evaluate the impacts on biodiversity, plant production, and carbon sequestration capacity; and finally, determine the Spatio-temporal, socio-economic and biophysical criteria for scaling up.</p>	<p>Issoufou, Hassane Bil-Assanou Loireau, Maud</p>
<p><b>Agroforestry as a solution for building climate resilient technologies for farmers in Telangana India</b></p> <p>Agroforestry is a unique land management technique that combines agriculture, forestry, and/or livestock/pasture on the same piece of land in order to improve production, profitability, and environmental sustainability. The goal of the study was to learn more about the role of agroforestry in enhancing lives and mitigating climate change and to develop the climate resilient Agroforestry models in farmers field of Telangana. The data is acquired by a farmland household survey that is based on random sampling and an ex-post facto design in order to cover the whole area of study site and all the components available in the site. On-farm agricultural products provide the majority of their income, whereas tree and animal components serve as a supplement on their farms. Tree species such as <i>Tectona grandis</i>, <i>Azadirachta indica</i>, <i>Mangifera indica</i>, and <i>Syzygium cumini</i>, which collect carbon dioxide as their biomass, are kept by the farmers. The results pointed towards agricultural crops as a source of economic stability, crop variety, and soil fertility. The trees on the boundary operate as carbon sinks, lowering greenhouse gas emissions, implying that the trees/crops produced for subsistence have contributed to both economic stability and environmental sustainability by increasing total farm output and preserving the site's biodiversity.</p>	<p>Kumar, Nasam Midhun Singh, Alok Kumar</p>
<p><b>Low-cost agroforestry technologies for climate change mitigation and adaptation in Sub-Saharan Africa: A review</b></p> <p>Agroforestry encompasses a large set of technologies and innovations that have the potential to improve farm productivity with minimum environmental impacts in the context of climate change mitigation and adaptation (CCMA). In this study,</p>	<p>Assede, Eméline Sèssi Pélagie Biaou, Samadori Sorotori Honoré Chirwa, Paxie Valdés Velarde, Eduardo</p>

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<p>we discuss the relevance of agroforestry technologies and innovations for CCMA in Sub-Saharan Africa (SSA). We recorded and reviewed 172 publications and 61 scholarly works from the last 28-year period, starting from 1992 to 2020. The recorded Bibliometric data was classified and analysed using CADIMA tools. Finding indicated that comprehensive and well-developed technologies were used in the agroforestry system in SSA. They can be classified into ten main groups based on factors including the objective of farmers, the technique of biomass introduction in the crop field and the types of tree-crop association (Figure 1). The maximum positive effect of parkland technologies is obtained when tree density ranges from 20 to 40 trees/ha, indicating an increase of crop production by 915.9 kg. Globally, the returns to labour in fertilizer tree technologies outperform 17% those in natural fallow. Technologies in agroforestry contribute greatly to the REDD+ program. A well-managed improved fallow system may contribute between 100 kg N ha<sup>-1</sup> year<sup>-1</sup> and 200 kg N ha<sup>-1</sup> year<sup>-1</sup>. However, the best technologies with the highest benefit-cost ratio associate to a great CCMA effect could be the intercropping and improved fallows systems. The lack in detail economic, social and environmental costs of each technology with regard to specific context should be filled for effective rational decision-making farmers in their adoption.</p>	
<p><b>Dynamic agroforestry - a tool for successful smallholder-grown cocoa in times of climate uncertainty</b></p> <p>More than half of the world's cocoa (<i>Theobroma cacao</i>) grows in monoculture-like systems in West Africa that are vulnerable to climate change. Dynamic agroforestry (DAF) - a novel approach characterized by high plant diversity, density and pruning intensity, as well as systematic stratification - has the potential to restore soil fertility, mitigate and adapt to climate change, whilst improving the livelihoods of millions of smallholders. However, we need to know more about DAF's feasibility for West African farmers and about the factors ensuring their socio-economic sustainability. We have been conducting bio-physical and socio-economic research in two DAF projects in the Eastern and Western Regions of Ghana since 2018 and compared the results to traditional cocoa cultivation. We observed a significant improvement of soil fertility under DAF in the first four years after cocoa establishment. Cocoa vigour and survival rate were significantly higher in DAF, which strongly correlated with lower air temperature amplitude, as well as lower temperature and higher moisture content in the topsoil. 319% higher diversity and 98% higher density of shade trees compared to traditional plots demonstrate the high ecological value of DAF. DAF needed substantial investment in terms of planting materials and labour, which allowed for abundant harvests of a range of by-crops, but did not lead to economic competitiveness in the first year after establishment. Data from several years after establishment is currently being put together to get a more comprehensive picture of the productivity and profitability of the systems during the establishment phase of cocoa. According to interviewed farmers, the main hindrances for the large-scale adoption of DAFs are financial and logistical challenges associated with the high number and diversity of seeds and seedlings planted, suggesting that cooperation among value chain actors is key for successful DAF establishment and maintenance on a system-relevant scale.</p>	<p>Andres, Christian Barthel, Matti Dzade, James Henry Schmid, Katherine Koog, Ivanoé Milz, Joachim Schneider, Monika Dawoe, Evans Heid, Petra Six, Johan</p>

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<p><b>Fast growing species, interesting wood for climate change mitigation: case of <i>Acacia auriculiformis</i> in Benin</b></p> <p>In the face of increasing wood demand, deforestation and climate change challenges, fast growing species are a current solution. However, the ability of fast growing species in agroforestry systems to contribute to bridging the gap between wood demand and supply and climate change mitigation depends among others on the properties of the species, which vary based on locality. The objective of this study was to evaluate the potential of <i>Acacia auriculiformis</i> wood in Benin to supply wood in a sustainable way. We investigated the anatomical characteristics, the carbon content and the natural durability of the wood. The current work sought to complement data on the productivity and physico-mechanical properties of the wood that have already been determined in a previous study. Heartwood samples were obtained from <i>A. auriculiformis</i> trees from pure plantations (4 to 29 years old), in South Benin. Direct laboratory quantification methods were adopted to analyze the properties earlier mentioned. The results indicate that the species has a high proportion of fibers (58%), which are quite long (840 <math>\mu</math>m to 3510 <math>\mu</math>m), an organic carbon content of 35%, and is moderately durable to very durable against termite infestations. The species thus has strong potential for timber, renewable bioenergy and pulp and could be valued to supplement the wood supply from natural forest and contribute to climate change mitigation.</p>	<p>Tonouéwa, Jesugnon Fifamè Murielle Biaou, Samadori Sorotori Honoré Boadu, Kwadwo Boakye Assédé, Emeline Sessi Pélagie Amoah, Douglas Ebanye, Emmanuel</p>
<p><b>Biodiverse agroforestry systems are more efficient than secondary forests to restore Carbon stock on degraded lands in Amazon</b></p> <p>The rapid degradation and conversion of tropical forests result in huge carbon (C) losses to the atmosphere and persistent degradation of soils and social well-being. In the Amazon, the reaching of a tipping point where the forest would be replaced by low diversity savannah-like ecosystems threatens the global climate through a drastic reduction of water fluxes. In a such catastrophic context, Nature-Based-Solutions (NBS) are presented as the most efficient to restore C stocks and related ecosystems' functions. Here, we present the results of three studies that support the efficiency of agroforestry systems (AFS) to restore C stocks on poor soils from the Eastern and Western Amazon of Brazil and Bolivia. On very degraded soils after mechanized agriculture, AFS were much more efficient to re-establish aboveground C stock (<math>4.5 \pm 3.9 \text{ Mg} \cdot \text{Ha}^{-1} \cdot \text{y}^{-1}</math>) than natural regeneration (<math>0.2 \pm 0.2</math>) in a short-term experiment (2012-2018). On moderately degraded soils after slash-and-burn agriculture, old AFS were as or more efficient than secondary forests to restore C stocks. Shaded coffee AFS in Bolivia (20-30 y) fixed <math>69.9 (\pm 6.9) \text{ Mg} \cdot \text{Ha}^{-1}</math> while secondary forests (50-60 y) fixed <math>58.1 (\pm 7.6) \text{ Mg} \cdot \text{Ha}^{-1}</math>, in Brazil old AFS (30 y) were 11% more efficient (<math>57.1 \pm 6.7 \text{ Mg} \cdot \text{Ha}^{-1}</math>) than a secondary forest with the same age (<math>35.7 \pm 7.3 \text{ Mg} \cdot \text{Ha}^{-1}</math>) to accumulate C. Nonetheless, 30 y AFS or secondary forests in Brazil only recovered 38 and 27% of the original forest aboveground C stock. Soil carbon remained unchanged in all three studies. Despite the considerable potential of NBS as secondary forests or biodiverse AFS to fix carbon and improve the local populations' well-being, recovering original forest C stock is not feasible in the medium-term, and NBS must not be used to offset original forest losses. Forest conservation is a global priority and NBS should be promoted as a transition strategy for sustainable production systems.</p>	<p>Guillaume, Rousseau Gómez-Cardozo, Ernesto Celentano, Danielle Gehring, Christoph</p>
<p><b>Agroforestry perennials reduce nitrous oxide emissions and their live and dead trees increase ecosystem carbon storage</b></p> <p>Agroforestry systems (AFS) are recognized as sustainable agroecosystems that can contribute to climate change mitigation. However, differences in the management</p>	<p>Gross, Cole Bork, Edward Carlyle, Cameron Chang, Scott</p>

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<p>of AFS may affect greenhouse gas emissions and carbon (C) sequestration. In this 3-y field study conducted in central Alberta, Canada, we assessed greenhouse gas emissions and various C stocks across two common AFS (hedgerows and shelterbelts) and their component land-use types: perennial vegetated areas without trees (grassland), with newly planted saplings in grassland, and with mature trees (woodland) and adjacent cropland. Between 2018 and 2020 (April–October), methane uptake was 3.65 times greater under perennial vegetation, on average, relative to the cropland, while nitrous oxide emissions were 9.42 times greater in the cropland. In 2020, heterotrophic respiration was 2.15 times greater in the hedgerow woodland relative to the shelterbelt woodland (600 and 279 g C m<sup>-2</sup> y<sup>-1</sup>, respectively). Within the woodland, deadwood C stock was positively correlated with annual heterotrophic respiration and cumulative (to 100 cm depth) soil organic C, water-soluble organic C, and microbial biomass C. Total ecosystem C was 1.74–2.44 times greater in the woodland relative to the other land uses (178, 225, 249, and 434 [321 and 547 for shelterbelt and hedgerow, respectively] Mg C ha<sup>-1</sup> for the cropland, saplings, grassland, and woodland, respectively). Soil was the largest contributor to total ecosystem C in the woodland (63.6%), followed by biomass (30.1%), deadwood (4.0%), and litter (2.3%). Deadwood was an important C stock in the hedgerow woodland (34 Mg C ha<sup>-1</sup>) and also affected C dynamics, likely due to its role in enhancing soil labile C and microbial biomass. Our findings emphasize the importance of AFS for climate change mitigation, particularly retaining hedgerows (legacy woodland) and their associated deadwood, and support a shift in shelterbelt management to more natural woody perennial buffers to foster C sequestration.</p>	
<p><b>Carbon stocks and biodiversity in the tree-based land use systems of central Kerala</b></p> <p>Tropical homegardens have high potential for accumulation of biomass and soil carbon and for conserving biodiversity. Multiple factors, however, can influence carbon sequestration and species richness. To evaluate the effects of size of homegardens and its location along an altitudinal gradient in the Western Ghats on carbon stocks and species richness, field surveys were conducted in four districts of central Kerala, India (181 homegardens) along a transect from coastal plains to the High Ranges. Comparisons were made with other land use types such as rubber plantations, coconut groves and natural forests. Average aboveground standing stocks of carbon in the homegardens ranged from 6 to 58 Mg ha<sup>-1</sup>. Size of the gardens was a major determinant of carbon stocks per unit area, which decreased in the order small&gt;medium&gt;large. Although increasing stocks of carbon with altitude was postulated, no such trends were discernible (Figure 1), implying that managerial interventions play a cardinal role in determining carbon stocks than site elevation. Forest ecosystems had the highest aboveground biomass carbon stocks, which was followed by rubber plantations, homegardens and coconut plantations. Aboveground carbon stocks in the forest ecosystems ranged from 151.3 Mg ha<sup>-1</sup> to 765.2 Mg ha<sup>-1</sup>. Species composition and the level of biotic and anthropogenic disturbances are cardinal determinants of the standing stocks of carbon in forest ecosystems. The count of individual plants and species per homegarden also showed considerable variability, implying the role of holding size and management, besides locational attributes in determining species richness. Simpson’s diversity index of the sampled homegardens ranged from 0.55 to 0.84 and Shannon index ranged from 1.34 to 2.34, signifying moderately high species diversity for homegardens. The natural forest ecosystems, however, had much</p>	Kumar, B. Mohan



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higher diversity than the managed systems. Nonetheless, managed ecosystems such as homegardens play a vital role in conserving species diversity.	
<p><b>Agroforestry: Modelling on-farm fuelwood production of intercropped <i>Gliricidia sepium</i> systems in semi-arid Tanzania</b></p> <p>Background: Fuelwood is the main source of cooking energy in rural Tanzania; the dependency on fuelwood from off-farm sites is high. Agroforestry is a promising tool for land restoration and improving livelihoods. Objectives: For most on-farm grown trees, allometric models do not exist, limiting the production of biomass for use (fuelwood) or carbon accounting. The objective of this research was to quantify fuelwood production and develop appropriate allometric models to non-destructively determine above-ground woody biomass (AGWB) production. Methods: Two cropping systems (1) maize + <i>G. sepium</i> and (2) maize + pigeon pea + <i>G. sepium</i> were analysed over a period of 7 years. <i>G. sepium</i> stems were destructively sampled and coppiced twice per year; dendrometric variables such as root collar diameter, stem height, and AGWB production per stem were assessed to fit production and regression models. Results: The measurements show that AGWB production of <i>G. sepium</i> per cropping system increased each year (Figure 1) indicating that the natural log-transformed model <math>\ln\_AGWB = a + b * \ln(RCD20)</math>, with <math>a = 3.427</math> and <math>b = 2.54</math> is best suited to predict AGWB production (Correction factor = 1.022, <math>R^2 = 95.7\%</math>). Discussion: Due to the reoccurring coppicing of <i>G. sepium</i> plants, the number of sprouts per plant and its AGWB production increased over the years. The log-transformed linear allometric prediction model was selected because it provided the best-fit relationship between independent (RCD20) and dependent (AGWB production). Two explanatory variables within the models do not improve the accuracy of prediction. Conclusion: Fuelwood of <i>G. sepium</i> contribute to energy autonomy of households, reducing the dependency on fuelwood from off-farm sites. The developed allometric models support farmers to ex-ante estimate the area and number of <i>G. sepium</i> plants needed to meet their energy production targets.</p>	<p>Hafner, Johannes Michael Sieber, Stefan Uckert, Götz Temu, Emmanuel Steinke, Jonathan Kimaro, Anthony Anderson</p>
E. Transitioning to Food Security and Health	
<p><b>Integrating agroforestry into cropping system: impact on crop yield and their nutritional composition</b></p> <p>Background: Soil degradation is a global concern most prominent in the tropics and subtropics. In Cameroon, agriculture remains one of the most important sectors accounting for 44% of the GDP and 70% of employment but conventional intensive production systems cause adverse effects on soil structure, biodiversity and plant composition; thus, the need for production systems that enhance agronomic productivity and environmental performance. Agroforestry is one such potentially sustainable way of achieving healthier soils for increased agricultural production and improved plant composition. Objective: This work aimed to assess the effect of trees in the cropping system on the yield and nutritional composition of maize, groundnut, cassava, cocoyam, beans, yam and pepper in six regions of Cameroon. Method: A two-treatment experimental design was set up in the Centre, West, South, South-West, Littoral and Far North regions. Plants were sown and monitored. Mature samples were collected and used for the determination of the water, protein, starch, carbohydrate, lipid and ash content using standard analysis methods. The yield was determined by harvesting on a plot a fixed number of plants and weighing the consumed part. The results were compared to</p>	<p>Djouhou Fowe, Michelle Carole</p>



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those of samples collected from plots without trees at $p \leq 0.05$ . Results: The water content ranged from 60 to 92g/100g and was higher in agroforestry plots than bare ones. The protein content of groundnut and beans was more important in agroforestry systems in the Centre, West, South-west, South and Littoral regions (with values ranging from 17 to 29g/100g and from 7.59 to 12g/100g respectively for groundnut and beans). The lipid, starch, carbohydrates and ash content of the samples was also influenced by the presence of trees on the plot even if it was to take into consideration tree density per plot. Conclusion: Adoption of agroforestry in cropping systems contributes to increasing plant yields and composition.	
<b>Are trees determinants of food security in Sahelian areas agroforestry parklands?</b> Numerous studies suggest that agroforestry parklands contribute to several dimensions of food security (FS) (e.g. Koffi et al., 2020): direct consumption, indirect effect on soil fertility and pest regulation, contribution to income or to fuelwood. Yet, the majority of studies focus on explaining pathways qualitatively, but few provide quantitative evidence of the global contribution of trees to households' FS. This study measures to what extent trees are determinant of farming households' FS in two contrasted parklands of the Groundnut basin in Senegal. In addition to qualitative appraisal and descriptive statistics, we run a Tobit model on 412 households dataset to test whether trees and their uses are associated to improved FS, controlling for socioeconomic and farming factors likely to influence FS as well. Various variables were considered: number of trees, density, species richness, intensity and location of tree product collection through the year and the use of trees as a coping strategy during lean months (dummy). FS is measured using the Household Food Insecurity Access Scale. All else held constant, no significant contribution of number of trees and species richness to FS were found. However, the higher trees density in plots, the more the household is food insecure. The model also demonstrated significant positive correlations between a greater use of trees through the year and during lean months and the level of food insecurity. Trees are at the heart of the most food insecure households strategies both within (higher tree density and use) and outside their own plots (increased reliance to neighbour/common areas), both through the year and during lean months periods. While this does not lift them out of food insecurity, it indicates the importance of guaranteeing trees access to the most vulnerable.	Sirdey, Ninon Jahel, Camille Faye, Ndeye Fatou Leroux, Louise
<b>Scrutinizing the direct and indirect roads connecting tree diversity to food security: A case study in two contrasted parklands of Central Senegal</b> Most previous studies analyzing the agroforestry parklands-food security nexus have considered only tree cover. We propose an original empirical approach that combines the analysis of spatial data on parkland diversity with agricultural field monitoring and household surveys. These three sources of data were used to scrutinize the direct-indirect contributions of tree diversity to food availability (i.e. millet yield) and food access (i.e. the Household Food Insecurity Access Scale-HFIAS). Two contrasted parklands of Central Senegal were chosen as case studies. Firstly, we used a Gradient Boosting Machine (GBM) algorithm to disentangle the relative contribution of landscape diversity, biophysical and crop management variables in explaining millet yield variability. The GBM model explained 77% and 84% of yield variability for the two parklands, respectively, with landscape diversity variables accounting for 53% and 47% of relative influence. Among the landscape diversity variables, tree species richness and tree density were the most important variables. Secondly, we investigated the pathways linking parklands	Leroux, Louise Faye, Ndeye Fatou Jahel, Camille Falconnier, Gatien Diouf, Abdoul Aziz Ndao, Babacar Balde, Alpha Sirdey, Ninon Corbeels, Marc Baudron, Frédéric Bouquet, Emmanuelle

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diversity to HFIAS using a Correlation Network Analysis (CNA). Our CNA showed that greater tree cover and larger tree patches were moderately correlated to HFIAS. This may suggests that tree species with large crown, as it the case for most fruit bearing tree species in the region, are the main species contributing directly to food access. Tree diversity contributed mainly indirectly to household food access by improving household food availability. Our study shows that tree diversity matters as much as the amount of tree cover for the production of food, and it can contribute to improve food security. We bring a more nuanced picture to the contribution of tree diversity to food security suggesting that land management policies supporting food security should consider both tree density and tree species diversity to optimize the co-benefits of trees on the different food security dimensions.	
<b>The "One Health" concept to support cocoa agroforestry in Cameroon</b> The conventional intensification of agricultural practices (pesticides, energy, chemical fertilisers) based on the homogenisation of agriculture (variety, cropping systems, production function) is a source of increasing risks and threats to human health (exposure to pesticides), animal health and environmental health (biodiversity). It is becoming essential to renew the conceptual frameworks that guide public policies in order to transform agricultural practices by taking into account their consequences on the health of humans, animals and ecosystems. This systemic and integrated vision of health structures the evolution of the "One Health" concept. Its operational translation in the context of African countries and in Cameroon requires the constitution of knowledge communities (scientific and non-scientific). This experiment documents how 'One Health' can be designed as an interactive field of application between these communities on agroforestry. It mobilises bibliometric analysis, semi-structured interview surveys and the organisation of webinars in cocoa-based agroforestry systems that tend to be pesticide-intensive and whose extension is a source of deforestation in tropical environments. The results highlight how the mobilisation of the "One Health" concept allows: (i) to define the health of agroforestry ecosystems as a lever for the agroecological transition and (ii) to prevent the risks of emergence of various diseases linked to deforestation. They underline the need not to focus or reduce "One Health" initiatives on infectious diseases of humans and animals alone, but the interest for the governance of agricultural practices to extend it to the constitutive relationships of integrations between cultivated ecosystems and food systems. In conclusion, the experience confirms how the notion of a health structures renewals in the interaction of knowledge communities (scientific, public governance and rural communities) in the governance of orientations (project design, institutional strategies) more favourable to the socio-ecological sustainability of cocoa production.	Temple, Ludovic BAYIHA, Gérard De La Paix
<b>Agronomic Zn biofortification and use efficiency under different N and Zn scheduling of alley cropped-pearl millet</b> The availability of the nutrients, especially nitrogen (N) and zinc (Zn) during the specific plant growth stage, is critical for attaining the better yield and nutrient use efficiency. With the aforementioned objective in mind, an agronomic experiment consucted at the Agriculture farm of Rajiv Gandhi South Campus-Banaras Hindu University, Mirzapur, Uttar Pradesh during the Rainy season (Kharif) of 2017. The experimental crop, i.e., pearl millet ( <i>Pennisetum glaucum</i> ), was sown in the alleys of ten-year old custard apple ( <i>Annona squamosa</i> L.) orchard planted at 5 x 5 m distance comprising two factors replicated thrice. Factor-I comprises of 4-N scheduling [no N; ½ [basal] + ½[3rd visible leaf (VL)]; ¼ [basal] + ½ [3rdVL] + ¼	Verma, Kamlesh Prasad, S.K. Singh, M.K. Kumar, Raj Sharma, Prashant

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<p>[panicle extended in flag leaf sheath (PEFLS)]; ½ [basal] + ¼ [3rdVL] + ¼ [stigma visible (SV)]. Factor-II also consist 4- Zn scheduling's [No Zn; 2.5 kg ha-1 [basal] + 0.25% spray (*) [panicle initiation (PI)]; 2.5 kg ha-1 [basal] +0.25% [PI]*+ 0.25% [PEFLS]*; 2.5 kg ha-1 [basal] + 0.25% [50% stigma emergence (SE)]* + 0.25% [milk stage (MS)]*. N schedule at ¼ [basal] + ½ [3rdVL] + ¼ [PEFLS] recorded the maximum yield, nutrient content, uptake, and nutrient use efficiency. Similarly, the maximum grain yield, nutrient content, uptake, and nutrient use efficiency observed in the Zn at 2.5 kg ha-1 [basal] +0.25% [PI]*+ 0.25% [PEFLS]*. Conversely, application of Zn at 2.5 kg ha-1 [basal] + 0.25% [SE]* + 0.25% [MS]* recorded the maximum biological and straw yield. N and Zn interact significantly for yield, nutrient content, uptake, and partial factor productivity of applied N and Zn. Overall, the study establish that there are new opportunities for managing the N and Zn fertilizers more prudently and efficiently in alley cropped-pearl millet to promote the sustainability and livelihood of the farmers located in semi-arid regions.</p>	
<p><b>Status of traditional agroforestry systems in changing climate: A case study in Western Himalayan Region, India</b></p> <p>India is the cradle of agroforestry with diverse kinds of agroforestry (AF) systems practised since time immemorial. The tropical, subtropical, and temperate AF systems are among them. Temperate agroforestry is mostly practiced in India mainly in the Western Himalayan Region (WHR), where various forms of hill agriculture co-exist with a wide range of tree species in around 13.6 per cent of the geographical area of WHR. Growing naturally regenerating tree species along the boundaries of agricultural fields is an age-old practice in the WHR. The current study was conducted in the mountainous villages viz., Salamkhet (Site 1), Guryali (Site 2), Maun (Site 3), and Kudi (Site 4) of Tehri Garhwal, Uttarakhand, India, located between elevations of 1400-2000 meter above sea level (m asl), in response to the rapid deterioration of the rainfed hill agroforestry system. The main goal was to analyse the status and effects of numerous factors on this centuries-old indigenous agroforestry system. According to the survey, farmers in Uttarakhand selected villages raised a total of 24 herbaceous food crop species and 18 woody species. During the survey, a total of 28 plant species were identified that are found in the agroforestry system and are utilised by traditional healers to treat a variety of diseases. <i>Echinochloa frumentacea</i>, <i>Eleusine coracana</i>, <i>Panicum miliaceum</i>, <i>Setaria italica</i>, <i>Oryza sativa</i>, and <i>Triticum aestivum</i> were the most common cereals grown by farmers. The indigenous farming system, known as Baranaja in the area, centred around the production of more than 12 different types of crops. Rainfed farming, youth migration in search of work, and changing socio-economic and climatic conditions were all key factors in the agroforestry system's decline and abandonment of agricultural land.</p>	<p>Kukreti, Akshit Kurmanchali, Neelam Tariyal, Naveen Rawat, Laxmi</p>
<p><b>Explore the Economic Opportunities and Health Benefits of the Black Walnuts (<i>Juglans nigra</i>), American Elderberry (<i>Sambucus canadensis</i>) and Pawpaw (<i>Asimina triloba</i>)</b></p> <p>The black walnuts (<i>Juglans nigra</i>), American elderberry (<i>Sambucus canadensis</i>) and pawpaw (<i>Asimina triloba</i>) are among rapidly emerging new perennial non-timer forest products for the agroforestry systems in the U.S. Missouri has been one of the leading producers for production of these specialty crops. The aim of this project is to explore the novel uses of these specialty crops and their byproducts for the industries by systematically examining their health-promoting compounds. The specific objectives of the study include: 1) conduct scientific research in characterizing the health-promoting compounds in these specialty crops and its</p>	<p>Lin, Chung-Ho</p>

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<p>byproducts (juices, stem barks, leaves, fruits, and root extracts) through modern mass spectrometry, global metabolomic analysis and high-throughput screening bioassay protocol, 2) conduct a market research to identify potential uses and formulation of the identified health-promoting compounds from elderberry and byproducts for cosmetic, personal care products and pharmaceutical industries; and 3) examine the niche market of the identified value-added products. We have identified more than 143 bioactive phenolics which have been previously reported as bioactive agents that are important to human health. The anti-microbial, antioxidant, and anti-tumor properties of each compounds have been examined using high throughput screening assays. The anti-inflammatory properties of the extracts have been assessed in the human pro-monocytic cell line by evaluating the effects of the extracts on the expression of 13 human inflammatory cytokines/chemokines. A market guide has been compiled to provide information on health-promoting compounds from the plant materials and their potential uses in producing value-added products in the industries. The findings will increase the overall incomes of the chain production and benefit all the participants involved in the supply chain of specialty crops in agroforestry operations.</p>	
<p><b>School Plus Home Gardens in the Philippines: Nexus for Agroforestry and Organic Agriculture for Sustainable Nutrition and Food Security Among Children</b></p> <p>The School Plus Home Gardens Project (S+HGP) is a multi-institution-led project implemented in six pilot schools in Laguna Province, Philippines from 2016 to 2017. It aimed to introduce a participatory model for improving schoolchildren's nutrition by enhancing the existing school gardens through organic agriculture. The model actively engages teachers, students, and parents in maintaining organic school gardens and in establishing their own organic home gardens. Capacity-building was at the core of the model where teachers were trained, in turn training the students and their parents, on the principles and practice of organic agriculture (i.e., vermicomposting, organic pest management, organic fertilizer development, etc.) as well as participatory garden planning, monitoring, and record keeping. The model has now been scaled out to 100+ schools in the Laguna Province and is being introduced across other provinces in the Philippines. This paper highlights the role of agroforestry in this model, providing empirical evidence of its complementarity with organic agriculture. Experiences among the implementing schools show that multi-purpose trees in the schools like <i>Gliricidia sepium</i>, <i>Leucaena leucocephala</i>, and <i>Acacia</i> sp. have been essential organic farming inputs. Their leaves for green manure and mulch, substrate for compost and organic soil amendments, and for botanical pesticides. These trees in school gardens also provide ecosystem services that address specific requirements for organic agriculture. For example, <i>Moringa oleifera</i> bear flowers that improve pollination by bees and birds while serving as live fences for the gardens. Other agroforestry elements integrated in the organic gardens that were documented included highly nutritious vegetable shrubs (e.g., <i>Abelmoschus manihot</i> and <i>Corchorus olitorius</i>), small fruit trees (<i>Psidium guajava</i> and <i>Citrofortunella microcarpa</i>) and non-woody perennials (e.g., papaya, banana). Increased and sustained organic crop production with agroforestry components provided families with direct access to safe and nutritious food, consequently contributing to the community's food and nutrition security.</p>	<p>Calub, Blesilda Galang, Elson Ian Nyl</p>

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<p><b>Indigenous roots and contemporary applications of community orchards in the US</b></p> <p>Community orchards could play a valuable role as nature-based solutions to complex challenges we face today. In these unique plantings, a variety of nut- and fruit-producing trees and berry shrubs are often established together on public spaces to provide the community with healthy, fresh food. While interest in community orchards is on the rise, their roots can be traced back to Indigenous foodways which have persisted for millennia. The objectives of this presentation are to: 1) explore the history of community orchards in the United States, 2) identify ways in which these plantings could be informed by traditional ecological knowledge so they might contribute to community health and climate resilience, and 3) investigate opportunities for community orchards to address needs and preferences of contemporary Indigenous communities. The methodology includes a review and synthesis of the literature focusing on community orchards and related topics, as well as the presentation of a case study involving a project at Osage Nation in Pawhuska, OK, US. We found that community orchards support an array of functions, positioning them to contribute to solutions to major challenges related to food security, human health, and climate resilience. Based on our findings, we recommend community orchard projects should prioritize access for the community and link the programming to existing activities. Plant species that are well-adapted to the site conditions, culturally significant, and beneficial for human health should be encouraged. As the community orchard projects grow and expand, they might serve as a space for stimulating partnerships between Indigenous communities and educational institutions or other organizations. The establishment of culturally relevant community orchards may be one avenue for Indigenous peoples to take on leadership roles for climate change adaptation beyond the boundaries of currently designated reservations, to include traditional territorial regions.</p>	<p>Lovell, Sarah Hayman, Jann Hemmelgarn, Hannah Hunter, Andrea Taylor, John</p>
<p><b>Bio-resource flow in integrated aquaculture and agroforestry systems: A case study of Luwingu District, Zambia</b></p> <p>The development of aquaculture has improved food and nutritional security in the country of Zambia. Farming native tilapias can increase household fish consumption and income generation. Most fish farmers in Zambia are smallholders, residing in rural, northern provinces where water is abundant and demand for fish is high. Unfortunately, lack of markets and infrastructure restricts access to aquaculture feeds, a major regional management challenge. To supply feeds, farmers rely on integrated agriculture-aquaculture (IAA), a practice by which earthen ponds are integrated into existing farm enterprises. By-products from those enterprises (“bio-resources”) support fish production. In IAA, the types of farm enterprises, intensity of management, seasonality, and degree of integration influence the quantity and quality of aquaculture feeds available. Previous studies have recommended context-specific, extensive strategies to intensify the flow of bio-resources supporting IAA. Agroforestry may provide opportunities for IAA households experiencing feed shortage. Trees provide fruit and leaf products for fish feeding, as well as essential regulating and supporting services that improve the farm’s resource base. However, research regarding agroforestry in IAA is limited in Northern Zambia. Therefore, a study was conducted to: (a) understand IAA system dynamics and bio-resource use preference; and (b) determine if greater agroforestry integration increased feed availability for aquaculture. Participants were sampled from among fish farmers in Luwingu District. Questionnaires containing discrete and open-ended questions,</p>	<p>Johnson, Jacob W. Jacobson, Michael Syapwaya, Muleya Cole, Steven Karsten, Heather Lundeba, Mary</p>

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inventories, and ranking exercises were piloted in 2020 (n=30) and administered in 2021 (n=60). Interviews included on-farm tours and participatory resource mapping. Quantitative data will measure livelihoods, food security, as well as inputs and outputs from all farm enterprises. Analysis will include correlation, multiple regression, and ANOVA. Qualitative data will clarify enterprise management, challenges, and household labor allocation; themes will be identified via open and focused coding. Data collection is ongoing; thus, the presentation will review preliminary results and conclusions.	
<b>Supplementation of <i>Moringa oleifera</i> leaves on milk yield and composition in cross bred dairy cows</b> Moringa oleifera Lam is a tropical plant belonging to family Moringaceae referred to as the 'drumstick tree'. Moringa is a drought tolerant plant that can be grown in diverse soils. Moringa is a good source of protein for dairy cows and can help farmers overcome the strong effect of dry season feed shortages on milk yield. Fresh Moringa has good intake characteristics, but it is necessary to have an adaptation period to allow cows to get used to the feedstuff. In the present study, the Moringa grown in the farmer's field and its nutritive composition was estimated. The feeding trial was under taken in Jersey cross bred cows under field conditions. The Crude Protein, Crude Fibre, Ether extract and Total Ash content was 22.38, 6.58, 7.08 and 9.41 percent respectively. The mineral analysis revealed that the moringa leaves are rich in Calcium (1.6%), Potassium -1.38%, Copper-5.90ppm, Zinc -38.02 ppm and Iron-285 ppm. Similarly the Vitamin C and Vitamin E content was 17.31mg and 113.70 mg respectively. The average milk yield in the Moringa leaves fed animal was 9.2 litres/day compared to the control animals (8.1 litres/day). Similarly the fat percentage of milk was 3.4 and 3.2 per cent in the test and control animals. The results of nutrient analysis and field demonstration on feeding value of Moringa leaves showed Moringa leaves are good source of protein and minerals and can be the potential source for animal feeding.	Chinnadurai, Kathirvelan Senthamaraikannan, Banupriy
F. Transitioning to a Viable Economy	
<b>Poplar based agroforestry as an economic source for renewable raw materials in irrigated agriculture in Central Asia</b> Poplars, planted as tree wind breaks, are the major agroforestry tree in the irrigated agriculture across Central Asia. Those tree wind breaks reduce water consumption of irrigated agriculture by 10% to 15% compared to crops without tree wind breaks, as found for the Ferghana Valley, a major bread basket in Central Asia [1]. With a harvest at a tree age of 15 years, tree wind break systems have the potential to increase farm income by 10% by current use [2]. Semi-structured interviews with farm households and wood traders revealed that poplar is used currently mainly for local furniture production and construction of roof trusses in rural areas. Poplar wood offers opportunities beyond current uses, such as in house construction ranging from insulation material to entire wooden houses. A shift towards such uses would spark further demand and increase farm incomes, while contributing to mitigate climate change by locking up carbon in wood biomass for extended time spans. The potential annual sustainable wood harvest from poplar tree wind breaks has been estimated to amount to 0.8 to 1.65 million m <sup>3</sup> roundwood, which meets the timber demand for the whole country [3]. These numbers stem from a GIS based analysis, in which different grids of tree wind breaks were intersected with Kyrgyzstan's irrigated croplands. In a recently	Thevs, Niels Welp, Martin Aliev, Kumar Roswag-Klinge, Eike Yuldasheva, Dilfuza Rizvi, Javed



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started applied research project, in which the authors are involved, energy efficient construction with agroforestry materials are explored, demonstrated and documented for educational purposes as a high value use option for trees from agroforestry systems. References: 1. Thevs et al. 2019: doi:10.3390/land8110167 ; 2. Thevs and Aliev 2021: doi.org/10.1007/s10457-021-00617-7 ; 3. Thevs and Aliev 2017: <a href="https://www.iufro.org/fileadmin/material/science/spps/spdc/FLR_page/FLR_Posters_Puerto_Rico_2017/Thevs_poster.pdf">https://www.iufro.org/fileadmin/material/science/spps/spdc/FLR_page/FLR_Posters_Puerto_Rico_2017/Thevs_poster.pdf</a>	
<b>Agroforestry as an alternative to diversify protein production and increase income in an innovative livestock-forestry integrated system in Brazil</b> The proposed agroforestry-livestock design aims to create a landscape solution that enhances animal welfare while providing a new source of income from NTFP as an alternative protein product in cattle-based systems. It's intended to be done optimizing forage production, diversifying herbaceous and shrub pastures, and including high-value trees in the system. Shade will provide thermal comfort for animals and increase the ADG (average daily weight gain) by around 40%. Developed in Porto Esperidião, MT, Brazil, the economic performance of the system relies on grains production (first four years), followed by the establishment of tree lines occupying different strata. Aiming economic viability, high added-value multi-purpose products were included in the arrangement: <i>Dypteryx alata</i> and cashew ( <i>Anacardium occidentale</i> ) as a nut-based protein source, <i>Acrocromia aculeata</i> for oil production, and <i>Myracrodruon urundueva</i> for timber. Trees start to produce in the five onwards. Focusing on conservative economic modeling, the expected gross revenue was estimated based on commodity market prices (July 2020). Furthermore, for <i>D. alata</i> , the almond alone was considered (not pulp or timber). For timber ( <i>M. urundueva</i> ) it was considered 30 years' cycle. Herd acquisition was not considered. CAPEX was diluted in 10 years. Land opportunity cost was USD 100 per hectare. Results show an implementation cost of 2,054.26 USD/hectare, an annual cost of approximately 668.62 USD, an average annual revenue of 6,817.55 USD, a net profit (after break-even) of 5,552.49 USD, with a net present value of 65,134.07 USD, and a breakeven in the year 4, and the payback in the year 14. Including the very detailed management of each phase, harvesting costs, the lifecycle of each plant, fluctuation and decline in production, as well as climate change calibrations for yields over time, we concluded that this system represents an excellent alternative for the expansion of livestock agroforestry-based farms in middle-west Brazil.	Costa, Paula Domiciano, Leandro Lemos, Everton Borges, Mateus Saka, Mariana Noronha, Felipe Ziantoni, Valter
<b>Transforming the Honduran livestock sector to contribute to a low-carbon economy: Maximizing trees on farm</b> Livestock is one of the most relevant sectors in the Honduran economy. It contributes 13% to GDP, generates 400,000 annual jobs, and supports 180,000 families. The sector is also an important GHG emitter, representing 9% of total emissions, reason why it needs to be transformed. However, migrating this activity toward a low carbon pathway while maximizing the economic welfare will require 1) Capacity-building to strengthen actors across the value chain, 2) financial support to catalyze the transformation, and 3) changes in the political arena to achieve an irreversible decarbonization. With the financial support of NAMA FACILITY, the Honduran's Ministries of Agriculture and Environment are leading the NAMA Support Project (NSP) "Transforming the Honduran livestock sector to contribute to a low-carbon economy". This five-year program seeks to align national extension programs to promote innovations that improve productivity, profitability, climate resilience while maximizing carbon sequestration at the farm level. The technical assistance is complemented with climate financing under	Sepulveda, Claudia Peguero, Felipe Andrade, Hernan Villanueva, Cristobal García, Edwin Escobedo, Adriana Avalos, Ileana Mendez, Juan Carlos Lizano, Daniela Pezo, Danilo Casanoves, Fenando Muhammad, Ibrahim

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<p>market schemes, which seeks to mobilize public and private financing. The NSP, jointly with national organizations, will create a Knowledge Management Platform tailored to different audiences to improve understanding of low-carbon solutions. The NSP will strengthen the sector's national governance creating the necessary alignments to guarantee the continuity of the livestock NAMA. The reduction of emissions and co-benefits at the farm level will be monitored through a digital MRV platform that will be integrated at the national level with an independent public institution, which will report the sector's contribution to the national mitigation commitments (NDC). The NSP will directly support the transformation of 1,200 farms, following a gender-inclusive approach, directly benefiting 13,500 people (i.e., employees, family members, extension officers, and loan officers). Altogether, the NSP expects to deploy about 1 million trees through Silvopastoral Systems and other incentives, while mitigating about 762 ktCO<sub>2</sub>e during its implementation and 5,328,250 tCO<sub>2</sub>e over ten years.</p>	
<p><b>Economic profitability and carbon sequestration through cereals under Harar and Aonla based agroforestry systems in India</b></p> <p>Agroforestry is a viable alternative to meet the demands of a rapidly increasing human population while conserving biodiversity. The experiment was premeditated to evaluate carbon stock (allometric equations) and economics under nine treatments with four replications in RBD. The highest biomass (77.80 t ha<sup>-1</sup>) and carbon stock (38.05 t ha<sup>-1</sup>) were recorded in maize + Harar. The maximum (80,471.49 Rs. ha<sup>-1</sup>) gross returns were obtained for maize + Aonla, yet maximum (42,684.40 Rs. ha<sup>-1</sup>) net returns and BC ratio (2.14) were found for mash + Aonla. Higher returns obtained with pulses indicate that pulses should be preferred over maize in agroforestry.</p>	<p>Bhatia, Avinash Kumar Pant, K S Sharma, Kamal Prakash, Prem Saakshi, Saakshi</p>
<p><b>Nature-positive supply chains for forest restoration through agroforestry systems</b></p> <p>Forest conservation and restoration and the safeguarding of livelihoods of local populations at the same time is one of the most important challenges in times of global climate change. Due to the import of products such as coffee or cocoa cultivation in tropical regions, consumer countries have a particular responsibility to ensure deforestation-free production of these goods. The BOSQUES project in Guatemala, funded by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and implemented by Heifer Guatemala and Defensores de la Naturaleza in cooperation with the German OroVerde Foundation, combines forest conservation with local economic development through approaches from forest landscape restoration on several levels. By establishing value chains for products from sustainable agroforestry systems, producers are supported in their local economic development. On the economic and political level, the project works on the creation of good conditions for nature-positive supply chains. At the same time, the establishment of agroforestry systems in the buffer zones of the protected areas means a restoration of tropical forest that provides ecosystem services such as carbon storage, water balance and harboring biodiversity, contributing to the conservation of the important primary forests of the core zones. The focus of the project is to strengthen producer associations in three protected areas in Guatemala in their organizational structure and capacity to build up value chains and market their products. In addition, long-term financial instruments and political framework conditions are enhanced for socially acceptable forest restoration. Smart sustainable corporate partnerships are created for the marketing of forest products from biodiverse agroforestry systems on the</p>	<p>Coy, Gerson Krings, Laura</p>

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international and national market. For this purpose, a platform will be established where producers and investors can search and find each other, thus enabling regulated investments from the private sector in forest reconstruction and facilitate access to sustainable deforestation-free products.	
<b>Profitability and climate risk mitigation of low carbon innovations for livestock farms in Mexico, Honduras, and Costa Rica</b> Governments in Latin America have a strong interest in reducing GHG emissions by transforming the Livestock value chain through various low carbon interventions. As a result, several countries have registered the NAMA Livestock as a strategic option to contribute to their Nationally Determined Contributions (NDCs), implying policy changes and deployment of financial mechanisms and capacity-building programs. However, the adoption of low-carbon innovations by farmers needs to be profitable and contribute to climate risk mitigation. In this paper, we evaluate the profitability of a custom-made intervention package for an average farm in Mexico, Honduras, and Costa Rica. A simulation model is used to forecast intertemporal biological and economic key indicators. Montecarlo simulation is used to capture the climate, yield, and market uncertainties. Preliminary results from Honduras show that the low-carbon intervention package of innovation improves farmers' capacity to cover the basic basket from 0.6 to 3.46 times. Furthermore, silvopastoral options reduce the impact of dry spells and heat stress, leading to more resilient cash flows to meet the farmer's food security needs. Finally, the estimated financial burden shows the need to have concessional loans, especially for small farmers implementing low-carbon innovations. Results are intended to complement extension programs in the region for the low carbon transition.	Peguero, Felipe

### G. Transitioning to a Viable Society

<b>Agroforestry and landscape planning, a territorial transition</b> The subject here does not propose to portray a fantasized idyll between farmers and planners, or a supposedly ideal model of a farming practice that would respond to all the problems of a structural crisis. Nor does it propose an aestheticizing or monographic vision of trees and hedges at all costs. Its objective is to provide a thinking on the essential transversalities between the complementary fields of planning and agronomy in the future of metropolitan territories. Its ambition is to offer a landscape and projector's view, on the possibilities of percolation and discussion between different worlds that have grown apart, sometimes opposed and whose recent history tries to tighten the links. Urban areas have sprawled and expanded on agricultural lands for the past 50 years, which rapidly led the public authorities to regulate and manage territories with zoning plans, conceived as soil protection policies. This zoning led to a specialization of landscapes. Peri-urban areas developed in logistics and commercial zones, sprawling on agricultural land in a complex peri-urban grid. In the same time the high mechanical optimization and deep changes in agricultural practices also led to massive changes in rural landscapes, a specialized and more productive lands where trees rapidly disappeared. This situation in Europe locally generated the implementation of agricultural protection zoning, regionally managed by the CAP since 2007 and Rural Development Programs (RDP). Environmental concerns appear in the CAP documents since 1992, with an	Lacourt, Simon Petit Berghem, Yves
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<p>indication about planting trees and hedges. This greening awareness has led to understand that urban and rural areas need a complexification of landscapes and a territorial 'despecialization' in peri-urban areas. Territorial transition needs structural instruments and institutional framework different from the existing ones. Agroforestry offers a hybrid solution for a transversality of actors and sustainable resources but can it also be a hybrid solution of planning, a new way of shaping the territory, in an innovative and reasonable way?</p>	
<p><b>Empowering Women in Sustainable Peatland Management with Agroforestry in West Kalimantan, Indonesia</b></p> <p>The prevalence of environmental degradation in peatlands has called for local leaderships. Recent literature suggests that women in peatlands bear family and social responsibility, while men are responsible for income generation, including by outmigration, due to limited livelihood options in peatland. In addressing women's untapped potential in playing significant roles in sustaining peat livelihoods, this study aims to examine women's current roles and obstacles in peatland management and identify ways to empower women. This study was conducted in August-November 2021, encompassing 27 villages in Kubu Raya, West Kalimantan. Our findings show that women's roles include managing the household, producing agricultural crops especially horticulture, helping in plantations, performing small trading, and being involved in various organizations. Men predominantly control the decision over land uses, while women help their husbands in farming. Women's role in managing horticulture is more marked than other land uses, such as plantations. Landholdings are quite low in this area; agroforestry is a good option to use land optimally, which at the same time allows higher access for women to use land due to the diversity of crops planted in one farm. 95% of women organizations are more active and mature than male-dominated organizations (e.g., farmer groups), with only 86% were considered active. However, for organizations and processes at the village level, most discussions were dominated by men, leading to, among others, limited public financing for women organizations. Alternative financial sources, e.g., religious-based community development programs, have benefited women organizations and can be further extended. In empowering women to play more significant roles in sustainable peat livelihoods and management, the study recommends 1) enhancement of women's participation in peatlands management through imposing gender equality rules; 2) promoting women-managed 'home garden' agroforestry practices to elevate household income, and 3) developing financing schemes targeted explicitly for women organizations.</p>	<p>Benita, Tania Ni Putu, Laksemi Dewi, Sonya Maharani, Sekar</p>
<p><b>Ecosystem contributions of Sudanian agroforestry parklands in their diversity. Scientific views vs. perceptions of local societies</b></p> <p>The parkland is a widespread rural agroforestry landscape in dry Sudanian Africa. The woody stratum produces goods and delivers ecosystem services that are essential for the well-being and resilience of rural populations. It also generates disservices that influence the density and composition of parkland in case of mechanised farming. Moreover, fallow land, where some species regenerate, is becoming scarcer, and soils fertility decreases. The result is a trend towards specialisation, ageing and thinning tree density. Before considering support for regeneration, the diversity of local situations requires a nuanced and contextualised analysis of the park's states and contributions, and listening to the viewpoints of the stakeholders. Within the framework of the Leapagri Ramses2 program, a participatory diagnosis of ecosystem services was carried out along a 50km regional transect of Koumbia-Dano (Burkina Faso), following mappings, an</p>	<p>Serpantié, Georges Maiga, Abdul Aziz Bastide, Brigitte Loireau, Maud Douanio, Manaka Sawadogo, Abdraime Cathy, Clermont-Dauphin Madjelie Cangré Ebou, Dao Sanou, Josias</p>

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agroforestry inventory (264 plots of 0.8ha) and an in situ survey of the families of 67 inventoried fields. As a result, the classic tree ecosystem services (shade, biodiversity, carbon sequestration, infiltration, fertility, forest products) assessed from the inventory vary greatly between villages according to soils and the state of economic development. Farmers' views on the expected services (hierarchy, disservices) are complicated by divergent interests within the same household and between households, depending on the cropping systems adopted or the types of farm. There are also personal or philosophical expectations linked to traditions and social affiliations such as ethnicity, clan, religion, age class, gender and education. These studies on the diversity of parks and their complex contributions to societies complete the knowledge on specialised parks. The two scientific and endogenous perspectives also complement each other to serve as inputs to multi-stakeholder debates on engaging or not in the restoration of degraded parks.	
<b>Oil palm agroforestry as an alternative pathway towards forest transition</b> The monoculture oil palm plantations have been rapidly expanding globally in the last three decades. In Indonesia, forest areas have been disturbed by this rapid expansion. A significant size of forest areas has been converted into monoculture oil palm plantations both by large-scale companies and smallholder farmers. Jangka Benah Strategy program was initiated in 2018 to facilitate forest transition in those disturbed forest areas. This program supports the smallholder oil palm farmers inside the forest areas to transform into more sustainable livelihood within the forest landscapes. In this presentation, we would like to share our experience in conducting this participatory action research (PAR), particularly on how oil palm agroforestry (OPAF) could contribute to forest transition while maintaining the viable livelihood of smallholder farmers. Within this PAR, stakeholders, including smallholder farmers, have been actively involved in research activities. These include the formulation of forest transition trajectories within their monoculture oil palm farms, executing the plans, and monitoring the growth of the enrichment trees. This research revealed that smallholder farmers could smoothly adopt OPAF because agroforestry is a well-known farming technology in the study areas. Therefore, smallholders farmers could identify the benefits of OPAF to improve their household livelihood and its contribution to environmental improvement. Adopting OPAF also opens the opportunity to legalize their long-term access to forest lands through Social Forestry licensing. This action research has suggested three pillars to the successful OPAF as an alternative pathway towards forest transition in the study areas. First, available examples of OPAF practices in the fields will provide accessible information for stakeholders. Second, technical supports and supports on agricultural inputs from the institution at the site level, such as villages, forest management units, local universities, and NGOs, will stimulate the adoption of OPAF. Third, policies at multiple levels that consistently support the forest transition could accelerate the adoption of OPAF.	Susanti, Ari Marhaento, Hero Riyanto, Slamet Ardyansyah, Fiqri Permadi, Dwiko Budi Nurjanto, Handojo Hadi Budiadi, Budiadi Imron, M. Ali Ridho, Darmawati Madjid, Iqbal Nur Putri, Cahyani Andika Susanto, Guruh Nissauquodry, Stevie Vista Irawan, Bambang Baddak, Yanarita
<b>Gender role assessment in agroforestry-based peatland management in South Sumatra and West Kalimantan, Indonesia</b> Sustainable management of tropical peatland needs to address community's environmental and livelihoods issues simultaneously. Agroforestry is seen as land-use systems that facilitate community participation in sustainable peatland management. In promoting agroforestry, we need to understand the decision-making process at the household level, especially the role of women and men. This study aims to identify gender-specific land-use preferences and roles in decision-making in peatland management in two Indonesia's provinces with large	Trisnaning Laksemi, Ni Putu Sekar Martini, Endri Dewi, Sonya



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<p>peatland and recurrent fire incidences. The study was conducted in December 2020-June 2021, encompassing 342 respondents (34 villages) and 270 respondents (27 villages) in South Sumatra and West Kalimantan, using FGD and household interviews. The analysis showed that land use preferences differ among native and migrant communities and between women and men. Native farmers predominantly manage rubber monoculture and agroforest, while migrant farmers mainly cultivate rice and oil palm as monoculture systems. Women tend to have a higher level of interest in managing rubber and non-timber forest products. In making decisions over farming practices, men tend to dominate the process. However, in some households, joint decisions are made, such as the selection of the type of commodities and products, the timing, and marketing options. Women's role in making decisions is more marked in the native communities than in migrant communities. Despite their low influence in making decisions, women's roles in managing the farms are significant within the native communities. Women play an essential role in weeding, harvesting, and selling crops, while men are more into land preparation, pruning, pest and disease control, and fertilization. Seedling preparation and planting are jointly undertaken by men and women. In conclusion, to raise the adoption rate of sustainable farming practices, such as agroforestry, a program or policy needs to internalize aspects of gender and community structure (migrant and native community) in well-targeted strategies.</p>	
<p><b>Agroforestry and welfare: the experience of our family as home-gardeners</b></p> <p>The transition needed for a viable human future depends on different changes at all scales, including ourselves. This piece describes our family process to convert a 3,000m<sup>2</sup> low-diverse (S=9) backyard into a productive homegarden. It started in 2012 when we bought our house in the periphery of Raposa, Brazilian Amazon. The soil was exposed and eroded. During nine years, we took care of the soil with mulching and planted 59 tree species (~250 individuals) mainly natives (64%) for food (40), wood (6), medicine (4), green-manure (5), and beauty. We also manage a diverse organic kitchen garden (with vegetables, teas, spices, medicinal herbs, and unconventional food plants), animal husbandry (bees, ducks, chickens, earthworms, and fishes), and tree nursery. Our kids participated very early in all phases from seedling production, planting, harvesting, and processing (as for the coffee, cacao, nuts, dry-fruits, and pulp). Today we consume 27 trees species products, five bananas, and one plantain varieties. Overproduction is mainly donated, but some sales and exchange experiences happen. Even though it has a low impact on the family economy, our homegarden feeds our souls and gives us joy. It also has a potential positive impact on landscape conservation and restoration, the canopy is very closed, and the soil is covered by litterfall and pruning; thermal comfort is another benefit. Each year we see new native plant species arriving and wildlife visitors (including monkeys, fox, agouti, birds, and snakes); we have also registered a new biological interaction between an ant and a butterfly species. It may not be possible for most urban families to move to the countryside and grow an agroforest like us, but other attitudes can have a positive impact on nature. To know the origin of the products and boycott those related to deforestation and degrading social conditions is the first.</p>	<p>Celentano, Danielle            Celentano-Rousseau, Ananda            Celentano-Rousseau, Noam            Rouasseau, Guillaume</p>



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<p><b>Agroforestry promotion for enhancing resiliency of community-based forest management areas in the Philippines</b></p> <p>The national policy of the Philippine government for sustainable forest management called for the establishment of community-based forest management program, where upland dwellers in the state lands are being recognized as stewards of the forestlands. To meet the twin-goal of economic development and environmental conservation, agroforestry was placed at the core of the program implementation, being the primary technology intervention. An action research was implemented in the selected community-based forest management areas in 2019-2021 primarily to promote sustainability and resiliency of the local communities and the landscape through an enhanced agroforestry promotion. This action research employed resiliency assessment, land capability assessment for agroforestry, ecological assessment, capacity-building of the people's organizations, and the establishment of appropriate agroforestry models. Four agroforestry models were established based on the socioeconomic and biophysical conditions of the areas, and the potential economic and ecological contributions of the different components. These include two fruit tree-based agroforestry models where perennial crops particularly high-value fruit trees are the dominant components; vegetable-based agroforestry model, where high-value vegetable crops are the dominant components; and aquasilviculture, where mangrove areas are integrated with aquatic resources. Soil and water conservation measures were also established to control soil erosion in the sloping areas. Livelihood technologies that are based on the dominant crops in the communities were also introduced such as processing of turmeric into powder, and processing of coconut meat into copras. The local communities were trained on the technical and management aspects of the four agroforestry models. Harvests from the annual agricultural crops indicate a potential additional farm income to the farmer-cooperator, while harvests from the aquasilviculture provided an additional income to the people's organization. Integration of fruit trees was projected to provide economic and ecosystem services.</p>	<p>Visco, Roberto Landicho, Leila Ocampo, Maria Theresa Nemesis Cabahug, Rowena Esperanza Abadillos, Maryann Ramirez, Ma. Armie Janica Castillo, Arnold Karl Cosico, Russel Son</p>
<h3>H. Transitioning to a Viable Development</h3>	
<p><b>Restoration through Agroforestry Systems: a “new” development paradigm in the Brazilian Amazon</b></p> <p>In the Brazilian Amazon, 20% of the original forest cover has been deforested (80.3 million hectares) and a similar surface of forests has undergone degradation by fire and logging. At the same time, the ~28 million inhabitants of the region are among the most socially vulnerable in Brazil, and their plight has worsened during the COVID-19 pandemic. The Alliance for Restoration in the Amazon (Alliance) is an interinstitutional and multisectoral coalition established in 2017 with the main goal of promoting, qualifying, and expanding the scale of forest landscape restoration. Among the different restoration methods, Agroforestry systems (AFS) stand out as an excellent strategy to integrate production, conservation, and restoration. Indeed, highly diverse AFS have been used in the Amazon for thousands of years as the basis of subsistence for complex pre-Columbian societies. AFS can be used to meet environmental obligations through different models and arrangements adapted to multiple stakeholders, scales, and interests. In 2020, the Alliance conducted a systematic survey through both primary and secondary data collection and identified 1,643 AFS restoration initiatives in the</p>	<p>Celentano, Danielle Moraes, Miguel Ferreira, Joice Pinto, Andreia Freire, Rodrigo Ferreira, Thais Rangel, Livia Miccolis, Andrew</p>

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Amazon, encompassing 15,554 hectares (averaging 9.47 ha $\pm$ 40.79), most of which led by civil society (74% of the area). This survey did not capture all AFS in the region, as most rural populations have AFS in the form of subsistence homegardens. The use of agricultural and short-cycle crops can contribute to food security and income generation in the early years, in addition to covering part of the restoration costs. Scalable productive arrangements should consider species selection based on socioenvironmental and economic criteria, connections with other links in the value chains, agro-industrial processing plants, and marketing channels. Numerous successful cases show how restoration through AFS can generate jobs, income, and food security, among other direct and indirect benefits including critical ecosystem services.	
<b>Performance of agricultural innovation support services: the case of cocoa agroforestry in savannah in Cameroon</b> In Cameroon, the afforestation of degraded savannah through cocoa agroforestry is a grassroots innovation that is spreading on semi-arid lands. This study aims to understand the support services which drive the process of this innovation according to farmers and build performance indicators for those services. The data used were collected through individual interviews, focus groups, and workshops with farmers and other stakeholders of the process. Academic and non-academic literature was also used. The analytical process was mostly inductive. The Impact of Research in the South (Impress) ex-post approach serves to build the historical timeline. Then a thematic analysis serves to categorize the performance indicators. Starting in 1930, the afforestation of degraded savannah through the cocoa agroforestry process has three main phases. The first phase, from 1930 to 2003 is characterized by pioneers' experimentations and sensibilization of their siblings and the innovators beneficiated from generic public support services for the cocoa sector. During the second phase, from 2003 to 2014 the creation of local financing services and the intervention of international researchers leads to the identification of agroforestry associations with higher yields and accelerates the adoption of the innovation. During the third phase, despite the withdrawal of research, public and private support services, the innovation continues to spread through the migration of farmers. The main services identified by cocoa growers are first training to develop skills, then material and financial support to start and expand their activity. Generally, farmers evaluate performance with posture, attitudes, and competencies of service suppliers while the latter's criteria are quantitative. Generally, although farmers consider training as essential to build skills they aim to get autonomous from support services in their activity. These results call for the dedication of specific services to this innovation to reap the benefits of reforestation in semi-arid areas in Cameroon.	Soule Adam, Nawalyath Temple, Ludovic Mathé, Syndhia
<b>Application of Geospatial technology in Agroforestry: Constraints and Future</b> Geospatial technologies have enormous potential for mapping, monitoring and analysing the agroforestry's (AGF) inherent spatial complexity in any landscape, while providing new insight for planning and decision making. From the studies carried out so far, it seems that there are still various discrepancies associated with the AGF mapping mostly what to be included in the AGF or what not, selection of the dataset (temporal and spatial resolution), classifier, sampling techniques (sample size, sampling design, unit) and accuracy, which limit large scale implementations. The majority of methodologies focus exclusively on the simultaneous AGF system (alley cropping), leaving behind the sequential AGF system (shifting cultivation). Moreover, even in estimation of the carbon sequestration potential (CSP) of AGF practices, the C accounting models such as	Sharma, Prashant Bhardwaj, D.R. Singh, M.K. Verma, Kamlesh

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CO2fix model used with a lot assumption. Further, despite considerable advancement in UAVs and ability to precisely delineate the AGF area even up to individual species level and CSP, the use is very restricted and limited to few developed nations due to their expensive cost. Moreover, beside AGF extent or CSP mapping, the researchers should more focus on the AGF system's health assessment by assessing the physiological traits, leaf biochemical component and environmental stress such as water. In future, the accessibility of open access datasets (Landsat, Sentinel) and software's (QGIS, SNAP) or even development of AGF-specific datasets and software can help researchers to fully harness this emerging and frontier technology to get a better synoptic view of this widely accepted land use. The upcoming missions from BIOMASS and FLEX mission (ESA), Landsat 9 (NASA), NISAR mission (NASA-ISRO), TRISHNA satellite (ISRO-CNES) and test studies from international space station sensors such as GEDI and ECOSTRESS are paving the way for future developments and advancement to mapping and monitoring of AGF extents including, biomass and health with the high fidelity.	
<b>Comparison of Agroforestry suitability assessment using AHP and Fuzzy-AHP approach: a case study of Kangra district in Northwestern Himalayas</b> Climate change is expected to have an influence on agricultural and natural ecosystems around the world, hence new agricultural systems are needed not just to feed the world's rising population but also to reduce environmental damage. Agroforestry is one such major land use system, and there is no reason to believe that agroforestry systems will spread. Specifically, via agroforestry suitability analysis, the implementation of various agroforestry practises in degraded and wasteland areas. As a result, the current study used a geographic information system (GIS)-based analytical hierarchy process (AHP) and a fuzzy-AHP technique to assess and compare agroforestry appropriateness. Eleven criteria were considered, including four topographical parameters (slope, elevation, aspect, and hillshade), three vegetation parameters (land use land cover, normalised difference vegetation index, and normalised difference moisture index), one climate variable (precipitation), one soil parameter (soil fertility), and two other parameters (distance from road and stream) were weighted overlay as per the weights and sub-weights developed from AHP and fuzzy-AHP. However, in case of AHP, the rating was given to sub-weight on a scale of 1-9 by 1. The results showed that the highly and moderately agroforestry appropriate area using the AHP strategy is 18.65 and 33.90 percent, respectively, while the fuzzy-AHP approach reduced it to 9.19 and 23.59 percent. When fuzzy-AHP is used instead of AHP, the area under marginal agroforestry appropriateness and currently not suitable for agroforestry increases from 10.58 to 27.14 percent and 18.00 to 21.20 percent, respectively. In addition, there are no changes in the permanently unsuitable region for agroforestry. Overall, the current study aids policymakers in making choices and directing future research for a more efficient estimate of the agroforestry area and identification of relevant interventions for agroforestry adoption, development, and management.	Sharma, Prashant Bhardwaj, D.R.
<b>Developing a Professional Agroforester Certification Program to Advance Agroforestry Adoption in the United States</b> Despite proven economic and ecosystem benefits of agroforestry, adoption nationally remains low. Lack of awareness, understanding, and technical guidance are consistently cited as central to this disconnect. An engaged network of trained agroforestry technical assistance providers and practitioners equipped with knowledge, skills, and regional resources is necessary to effectively address context-specific barriers to adoption and sustain a long-term commitment to	Hemmelgarn, Hannah Gold, Michael Favor, Katherine

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<p>working group operations and continuing education in communities of practice. A professional certification for agroforestry, recognized as a necessary and missing component of agroforestry knowledge and adoption infrastructure (Hemmelgarn &amp; Gold, 2021), could substantially advance the scaling up of agroforestry nation-wide. Modeled after similar national society standards, the agroforester certification we present would effectively create dedicated and identifiable agroforestry assistance providers within regional agroforestry network hubs. The establishment of such a certification program will involve in-depth training through regional Agroforestry Academies (an intensive 60-hour education program currently consisting of online coursework and hands-on field experience), as well as participation in mentorship activities connecting existing innovative practitioners with prospective practitioners. Upon completion of these two primary activities, cohort members will be eligible to receive Professional Agroforester Certification, which may be maintained through annual completion of continuing education and outreach service hours. While there is currently some activity within each US region agroforestry working group, we expect that this effort will substantially incentivize new and continued commitments to sustaining educational opportunities regionally, while unifying national efforts and standards. A professional certification also has the capacity to enhance peer-to-peer network building between existing practitioners and technical assistance providers, many of whom are lacking awareness and understanding of agroforestry. Barriers related to land and capital inequities persist and must also be central to any undertaking related to agroforestry training, given the potentially higher risk and longer-term nature of these integrated agroecological systems.</p>	
<p><b>Enhancing smallholder carbon trading through the Principles of Agroecology</b></p> <p>Agroecosystems services may provide the means for simultaneously addressing climate change mitigation and food security and nutrition. Monetizing ecosystem services has been considered a reward for reducing emissions in agriculture and other economic sectors. Voluntary carbon market from the forestry and land-use category has hit records of traded volume in recent years, however, low carbon credit prices and high opportunity, abatement, and transaction costs have hindered the development of carbon projects, especially with smallholders. Here, we examine how could the application of agroecological principles assist in making smallholder carbon trading feasible and sustainable. Thus, we selected some major socioeconomic constraints of carbon projects for trading certified emissions reductions from agroforestry systems and ecological restoration and relate them to specific agroecological principles (P) from the High-Level Panel of Experts from the Committee on World Food Security (2019). Since smallholder farmers need to fulfill their needs their willingness to participate in carbon projects depends on the provision of co-benefits, either as better access to water and food, and direct or indirect economic returns, which should offset the opportunity costs. Increasing the number of farmers participating (P13) may reduce the fixed costs of carbon projects. If participation is properly promoted it also favors co-creation of knowledge (P8) and fairness (P10) among all stakeholders, which in turn, contribute to generating and disseminating information, considered another source of high transaction cost of carbon projects. Through improving resource efficiency (P1 and P2) and strengthening resilience (P3:P7), both the carbon budget and the farmers' food security and nutrition would be enhanced. Agroecology is, at the same time, a transdisciplinary science, a set of practices, and a social movement, and its principles may contribute to increasing our</p>	<p>Souza, Saulo Meier, Martin Amaral, Jimi Marques, Henrique Miccolis, Andrew</p>

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understanding of the main societies' challenges and assist in the proposition of solutions towards a viable world.	
<p><b>How are trees outside forests perceived in some rural areas of Lorraine (East of France)</b></p> <p>Here are presented the results of a survey, first step of an experiment conducted in two rural areas in Lorraine, dominated by mixed-farming. This experiment aims at developing a methodology for a participatory territorial design approach around trees outside forests (TOF). Around 40 local stakeholders (agricultural or not) were individually invited to talk about the place and the role that TOF have or should have in the rural areas studied. The qualitative interviews were facilitated by a set of 23 cards (playing card format), illustrating various issues related to agroforestry, the territory and the administrative environment. From these interviews, it appears that TOF are considered crucial to limit global changes and to adapt to climate change and maintain the quality of the living environment. They are perceived both as a heritage to be protected and as a responsibility towards future generations. As public goods, their management sometimes gives rise to misunderstandings and conflicts. As natural elements, they have an intrinsic value or must provide services to humans, even goods. The balance between the constraints they generate and the benefits they provide drives their disappearance or reintroduction in rural areas. They can promote the local supply of goods and the development of activities. However, their role in the local supply of firewood is controversial, while material wood and food are rarely mentioned. Their rehabilitation would require inventing new ways of life and social interactions in a common and altruistic project, of which future generations would be the main beneficiaries. This requires at least sharing costs and labour, relocating production and consumption, as well as training professionals and educating the inhabitants, especially the youngest. All this material feeds the following stages of the participatory project, with workshops aimed at informing, comparing points of view and finally imagining different possible futures.</p>	<p>Jondreville, Catherine Lacroix, Thomas Barataud, Fabienne</p>
<p><b>Propagating connections: Developing a network of agroforestry demonstration farms for shared knowledge, education, research, and community building</b></p> <p>The Savanna Institute Agroforestry Demonstration Farm Network was launched in 2018 with the multi-functional goals of increasing on-the-ground research in production systems, showcasing how farmers, landowners and communities can incorporate trees and perennial plantings into just, regenerative futures, and training the next generation of practitioners in the midwestern United States. In Spring 2020, as the world began to shut down, the Savanna Institute and its community partners established three demonstration farms across the US state of Illinois; in 2022, we are expanding that network with the addition of two new demonstrations. This interactive session will focus on celebrations of success and lessons learned through intentional partnership building, innovative land access and management, and the perennial struggles of time, labor, and capacity on the Savanna Institute demonstration farms and then invite session participants to share their own successes, roadblocks, and lessons learned. Attendees should be prepared to listen, share, and offer ideas and tools on how we can better connect agroforestry demonstration projects for stronger, more inclusive education, research, and outreach. This will be facilitated through guided small group discussions and the creation of an open-source interactive map. Attendees will leave this session with a network for future connection, resource sharing and collaboration that crosses borders and centers the voices of farmers, landscape</p>	<p>Adams, Kaitie</p>

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managers, researchers, and educators working with agroforestry demonstration projects.	
<p><b>Factors Affecting Farmers' Willingness-to-Adopt Agroforestry - A Case Study in Missouri</b></p> <p>Temperate agroforestry practices offer various ecological, social, and economic benefits, yet these systems are not prevalent on the US agricultural landscape. Furthermore, data surrounding adoption of agroforestry in the US remains unclear. A survey of Missouri agricultural farmers and landowners was conducted to determine the extent of agroforestry adoption in the state, current knowledge and perceptions of agroforestry, and interest in implementing agroforestry practices. A choice experiment model was employed to assess participants' willingness to accept payments for adopting agroforestry practices and to determine farmers' valuation of technical assistance and environmental benefits. Across the sample, self-reported agroforestry knowledge was minimal to low. Perceptions of agroforestry systems for management and economic aspects were generally positive, but perceptions of agroforestry for promotion of biodiversity and environmental services were especially high. Using a mixed logit regression model, if cost to establish a given agroforestry system was \$2,500 per acre, it was determined that the average Missouri farmer in our sample would accept a payment of \$7,697 per acre to implement agroforestry. Additionally, among those who were willing to implement agroforestry technologies, technical assistance was valued at \$1,670, while environmental benefits were valued at \$2,992. In a second model constructed to assess interaction variables, participants with greater knowledge of agroforestry practices were significantly more willing to adopt agroforestry practices, while those with larger farms and greater incomes were less likely to engage with agroforestry. Additionally, those who agreed with statements regarding agroforestry's ability to improve soil health were significantly more likely to express interest in implementing agroforestry practices. These findings enhance understanding of existing agroforestry plantings in Missouri and elucidate farmer perceptions, willingness to adopt, and factors influencing agroforestry implementation decisions. Additionally, these research findings may stimulate the creation of effective agroforestry outreach, education, or supportive efforts.</p>	<p>Stubblefield, Kelsi Cai, Zhen Lovell, Sarah</p>
<p><b>Mainstreaming Agroforestry into Spatial Planning Policy to Achieve Sustainable Development</b></p> <p>Agroforestry is a win-win solution in minimizing trade-offs between development and environment. As an integral part of livelihoods, agroforestry has been practiced in many diverse forms throughout Indonesia. However, lands managed as agroforestry have been continuously shrinking. This study aims to 1) unveil the policy dynamics that causes the booms and boost of agroforestry; 2) identify ways to raise awareness and recognition of the role of agroforestry as a nature-based solution for sustainable development. Forest policies that promote agroforestry are: i) Permenhut No 7/1990 that mandates Forest Concession Rights holders to improve the welfare of communities living around forests in 1990s; ii) Community's right over forest resources was introduced through the Community Forest (HKm) program; iii) In 2003, Indonesia declared Social Forestry as a national program (Minister of Forestry Regulation No. 01/Menhut-II/2004); iv) the agroforestry system is listed for the first time in the Indonesian regulatory system, namely in Permenhut No. P. 19/ Menhut-II/2012. This Ministerial Regulation provides opportunities for the development of agroforestry practices in Industrial Plantation Forests (HTI) and Community Plantation Forests (HTR). On the other</p>	<p>Johana, Feri Dewi, Sonya</p>



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<p>hand, there are still policy gaps, particularly: i) the absence of consistent agroforestry policy across sectors; ii) lack of recognition regarding the importance of agroforestry practices at the landscape level on ecosystem services; iii) lack of technical guideline to include agroforestry in spatial zoning, and iv) lack of cross-sectoral integration in supporting agroforestry development. This study found that huge area of terrestrial area of Indonesia is potential for agroforestry development to maintain, protect and restore multifunctional landscape that supports sustainable livelihoods and ecosystem services. We recommend that at higher policy level, agroforestry practices are recognized, promoted and incentivized. Measuring and monitoring agroforestry areas, ecosystem services they provide and livelihoods they support as key performance indicators are crucial.</p>	
<p><b>Can Oil Palm Agroforestry Contribute to Sustainable Management Practices in Indonesia?</b></p> <p>The first monoculture oil palm plantation in Indonesia was established in early 1910 in North Sumatra and slowly increased in area from 100,000 ha in 1940 to 200,000 in 1980. A sharp increase to 14 million to date was triggered by the emerging high demand for palm oil that places Indonesia as the world's biggest producer. 40% of oil palm plantations in Indonesia are managed by independent smallholders, usually with low productivity. The sector has contributed to non-oil and gas exports of 13.5% and Indonesia's GDP of 3.5% and has catalyzed rural development. However, the private benefits have been accompanied by social costs and environmental impacts. Expansion of oil palm plantations is often linked to deforestation issues. Main strategies to maintain production and avoid deforestation are replanting old trees, converting oil palm into agroforestry in forest areas, and helping independent smallholders increase productivity. Oil palm agroforestry may become an option for each strategy in promoting sustainable practices. Through agroforestry, ecosystem health can be maintained (controlling pest and diseases, protecting water sources and soil, using land more efficient from the perspective of land equivalent ratio, increasing biodiversity), while production function is achieved (long term and stability of income, meeting household need). A range of policies and programs (public and private) have been supportive in exploring and promoting such options. Nevertheless, development of oil palm agroforestry on various scales faces challenges i.e., lack of knowledge in designing and managing the agroforestry system and lack of access to green value chain and financing. We aim to promote oil palm agroforestry among independent smallholders in North Sumatra by (1) enhancing the understanding of oil palm agroforestry options and practices for independent oil palm smallholders, (2) developing capacity strengthening manuals and tool for farmers in designing and adopting oil palm agroforestry system.</p>	<p>Khasanah, Ni'matul Dewi, Sonya Martini, Endri</p>
<p><b>Fostering multifunctional landscape of Rejoso Watershed, Indonesia, through integrated watershed and water resource management</b></p> <p>A sustainable production landscape is multifunctional and critical to ensure the food security and ecosystem services provisions. In managing such landscapes, robust and evidence-based decision-making is needed to identify trade-offs and ways to minimize negative externalities. This research provides lessons in establishing integrated watershed and water resource management (IWWRM) in the context of production landscape using a case study in Indonesia. The IWWRM is designed by applying the concept of Theory of Change (ToC) and Theory of Place (ToP). A ToC portrays general strategic leverage on a socio-ecological system, thus producing a comprehensive description of how and why the desired change is</p>	<p>Leimona, Beria Khasanah, Ni'matul Dewi, Sonya</p>

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<p>expected to happen in a particular context. The ToC is essential to be firmly positioned in a Theory-of-Place (ToP) to reduce the chance of failure and increase the likelihood of success at scale. A ToP refers to a 'sense of place' and a sense of identity of people living in a landscape along with their history and future vision of the future. We identify the ToC by applying the Capacity Strengthening Approach to Vulnerability Assessment (CaSAVA) approach to capture the socio-ecological systems and respond to shocks and hazards. The targeted production landscape is the Rejoso Watershed of East Java, Indonesia. The watershed is an important catchment that provides vital livelihoods for the local communities, with high water demands for both industrial and domestic users. The research study discusses the production landscape of the downstream clusters dominated by irrigated paddy fields and sugarcane plantations, the midstream clusters by complex agroforest, and the upstream area, dominated by horticulture commodities such as potatoes, onions, cabbage, the state-production forest, and complex agroforest. Recommendations on how the empirical application of ToP and ToC is optimally reconciled to shape the way towards sustainable ecosystem services provisions from a production landscape are described.</p>	
<p><b>Sustainable bamboo management practices in smallholder's timber plantation system: economic performance &amp; farmer's perception</b></p> <p>In the Brazilian Amazon, 20% of the original forest cover has been deforested (80.3 million hectares) and a similar surface of forests has undergone degradation by fire and logging. At the same time, the ~28 million inhabitants of the region are among the most socially vulnerable in Brazil, and their plight has worsened during the COVID-19 pandemic. The Alliance for Restoration in the Amazon (Alliance) is an interinstitutional and multisectoral coalition established in 2017 with the main goal of promoting, qualifying, and expanding the scale of forest landscape restoration. Among the different restoration methods, Agroforestry systems (AFS) stand out as an excellent strategy to integrate production, conservation, and restoration. Indeed, highly diverse AFS have been used in the Amazon for thousands of years as the basis of subsistence for complex pre-Columbian societies. AFS can be used to meet environmental obligations through different models and arrangements adapted to multiple stakeholders, scales, and interests. In 2020, the Alliance conducted a systematic survey through both primary and secondary data collection and identified 1,643 AFS restoration initiatives in the Amazon, encompassing 15,554 hectares (averaging 9.47 ha <math>\pm</math>40.79), most of which led by civil society (74% of the area). This survey did not capture all AFS in the region, as most rural populations have AFS in the form of subsistence homegardens. The use of agricultural and short-cycle crops can contribute to food security and income generation in the early years, in addition to covering part of the restoration costs. Scalable productive arrangements should consider species selection based on socioenvironmental and economic criteria, connections with other links in the value chains, agro-industrial processing plants, and marketing channels. Numerous successful cases show how restoration through AFS can generate jobs, income, and food security, among other direct and indirect benefits including critical ecosystem services.</p>	<p>Erawati, Anisa Sabastian, Gerhard Eli</p>
<p><b>Five-decade trends of agroforestry research in Peru and Colombia</b></p> <p>Background: It is widely acknowledged that agroforestry can contribute to achieving several sustainable development goals. To channel future research for sustainable development efforts, there is a need to identify long-term research trends and knowledge gaps adequately. This review focused on Peru and Colombia, tropical countries that have historically produced globally traded</p>	<p>Villamonte-Cuneo, Gianfranco Parodi, Alejandro Valencia-Salazar, Sara</p>

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<p>agroforestry commodities such as coffee, cocoa, and livestock. Objective: Review, classify and identify main trends in agroforestry research in Peru and Colombia since the 1980s. Methods: A systematic literature review was performed using Scopus, Web of Science and Scielo. Duplicates and articles based on research outside Peru or Colombia were removed. The remaining articles were classified according to the country researched (i.e., Peru, Colombia), type of agroforestry system (e.g., agrosilvicultural), commodity (e.g., coffee), and research topic (e.g., carbon sequestration). Results: In total, 400 papers were reviewed and classified. For Peru (n=163), the main commodities represented in the scientific literature were coffee (15 %), cattle (14 %), and cacao (12 %); while the main topics were genetic resources with 12%, land use (7%) and soil (7%). For Colombia (n=257), the main studied commodities were cattle (54 %), coffee (20 %) and cacao (10 %); while biodiversity (17 %), soil (13 %) and animal nutrition (9 %) were the main research topics. Finally, while most research in Colombia focused on silvopastoral systems (52%), there was no specific trend in Peru. Discussion: A steady growth in agroforestry research was identified in both countries, especially in Colombia, where publications increased from less than 20 between 2000 and 2010 to more than 150 in the past decade. Nevertheless, considering that only 47% (n=188) of the articles were open access and that institutions from both countries face paywall limitations, it is critical to guarantee open access practices for future research. The focus on production-related factors and biodiversity evidence the relevance of agroforestry for SDG 2 (no hunger) and SDG15 (life on earth). There has also been research linked to SDG13 (climate action) via carbon sequestration. However, there are clear knowledge gaps for strategic food system research areas such as circular economy, food waste and losses, and reduction of environmental impacts along supply chains using a life-cycle approach. Conclusion: The past five decades of agroforestry research in Peru and Colombia have focused on the links between agroforestry and biodiversity, soil quality and genetic resources. Future agroforestry research should cover research questions with a systemic approach, looking beyond the farm and landscape levels.</p>	
<h3>I. Transitioning to Viable Policies</h3>	
<p><b>Survey of Missouri farmers to explore the potential of woody perennials to integrate conservation and production</b></p> <p>Agroforestry plantings can provide multiple benefits such as reduced soil erosion, decreased nutrient runoff, increased biodiversity, and greater farm income stability. This array of benefits makes them a promising ecological-based model for agricultural production that simultaneously achieves conservation goals. Despite the financial and technical assistance federal conservation programs can provide, many landowners are hesitant to enroll and take land out of agricultural production. This study examines the potential to use conservation programs to support agroforestry plantings in the state of Missouri. We also explore how the integration of food producing tree and shrub species may increase the likelihood landowners would commit to a conservation program. A survey was used to 1) understand farmer's perceptions of and preferences for different planting plans for their farm, 2) capture farmer's interest in participating in conservation programs to assist in the planting of trees and shrubs on their land, and 3) determine how demographic factors and farm goals influence farms willingness to plant agroforestry. Farmers were sampled from six geographic regions of the state</p>	<p>Kronenberg, Raelin Lovell, Sarah Thapa, Bhuwan</p>

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of Missouri using a stratification process where each county was sorted into an urban or rural category. From these strata, twelve counties were randomly selected, and a proportional sampling of farm addresses gathered from the county tax assessor offices were included in the survey mailing lists. Survey responses show farmers rate agroforestry plantings higher than typical agricultural management. The majority of farmers also expressed a future interest in enrolling in conservation programs and were more willing to plant agroforestry with either technical or financial assistance. Age, interest in conservation, and the presence of marginal land were all positively correlated with willingness to plant agroforestry. Income, farming experience, and land acreage did not play a significant role in willingness to plant agroforestry.	
<b>Unlocking the potential of agroforestry in sustainable peatland management through land use planning: case study in West Kalimantan and South Sumatra, Indonesia</b> Massive, unsustainable land uses of peatland areas in Indonesia have become a central issue in the nation's effort to meet the GHG emission reduction target. Expanded monoculture plantation, associated with peat drainage, release CO <sub>2</sub> and methane through subsidence and fire. Weak governance and scarcity of livelihood options lead to poor land use planning and management, driving unsuitable land uses. In meeting the various stakeholders' needs, land use planning has to balance economic and ecosystem functions in the short and long term through peatland utilization and management. Peatland accounted for 60.4% and 34.7% of the Kubu Raya district of West Kalimantan province and OKI district of South Sumatra province, respectively. Zonation of peatland differentiates between protection and production functions. We overlayed the actual land use/cover map of the recent year with peatland allocation, and we found that most land-use changes occurred in the production zone to boost agribusiness and agroindustry. To a lesser extent, some changes to estate crops, forest plantation, and agriculture occurred in the protection one. As an alternative to the intensive and monocultural uses, agroforestry, which has been practiced extensively, can be an option for sustainable management. Despite its potential in removing the segregation between forest and non-forest areas, agroforestry has not yet been recognized in the current land use planning regulation. Integration of agroforestry into land-use planning can be conducted through synergizing the detailed spatial planning with the development plan at the district level. An inclusive process can prevent land use mismatch (minimizing negative externalities) and promote compatible uses (generating positive externalities). The local spatial planning still needs to comply with existing peatland regulations and align with the aspiration of various land managers. This study provides policy recommendations for policymakers to explore the potentially win-win land uses from the lens of various land managers.	Benita, Tania Martini, Endri Pandiwijaya, Arga Dewi, Sonya
<b>A Unified Strategy for Justice &amp; Equity in North American Agroforestry</b> Events in recent years have highlighted a growing awareness of structural and systemic inequities and a need for urgent responsiveness to social and ecological crises across sectors. Agroforestry is no exception, with land and capital access disparities tied to race, ethnicity, and gender identities (Horst & Marion, 2019) which affect who can participate and how. Simultaneously, agroforestry adoption rates in the US remain low (National Agricultural Statistics Service, 2017) despite economic and environmental benefits recognized in academic literature for their significant climate change mitigation and ecological enhancement potential (Bentrup & MacFarland, 2020). To catalyze scaled implementation of climate	Hemmelgarn, Hannah Kreitzman, Maayan Adams, Kaitie

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resilient perennial farm and forest systems, a strategic and coordinated effort that specifically addresses issues of equity, justice, and local needs is required. To this end, we undertake a systematic review of agroforestry initiatives and organizations, analyzing their strategic plans and programs through the lens of structural equity. We show that many agroforestry initiatives either 1) do not consider issues of equity explicitly, or 2) have yet to translate intention into programming and action. We deeply examine how three leading agroforestry organizations (of which we are members) are considering actionable steps to strategically prioritize equity and justice in our work as we plan for the next decade: the Association for Temperate Agroforestry, the Center for Agroforestry at the University of Missouri, and the Savanna Institute. Through review and evaluation of our current capacities and practices, we present the bottlenecks and opportunities that shape our commitments towards a shared vision of equitable and scalable agroforestry.	
<b>Unlocking the potential of agroforestry in sustainable peatland management through land use planning: cases from West Kalimantan and South Sumatra, Indonesia</b> Weak governance and scarcity of livelihood options in peatland areas led to poor land use planning and management, is driving issues to meet the GHG emission reduction target of a country with large tropical peatland such as Indonesia. Inclusive green land-use planning that includes multiple actors' perspectives in balancing peatland's economic and ecosystem functions is expected to address those issues. Agroforestry is seen as a land-use system that supports community participation in maintaining sustainable peatland management. However, agroforestry is overlooked in the existing land-use planning. A combination of policy and spatial planning analysis of peat-dominated landscape in two provinces (West Kalimantan and South Sumatra) in Indonesia was conducted to unlock the potential of agroforestry in green land-use planning that supports sustainable peatland management. The spatial land use analysis of the actual land use/cover map of the recent year with peatland designation shows that most of the land-use changes in peatland support the district's development plan, which is sometimes not aligned with the peatlands land zonation. From various land use systems identified in the peatland areas, agroforestry can become an option for more sustainable agricultural practices that address district targeted development plans while maintaining the peatlands' ecological function through green growth development. Despite its potentials, agroforestry has not yet been clearly recognized in the current district land use planning policies. An inclusive process in synergizing spatial planning zonation of peatland management with the district development plan, is expected to unlock agroforestry potentials to support win-win solutions in sustainable peatland management, from the perspective of the various land managers.	Pandiwijaya, Arga Benita, Tania Martini, Endri Dewi, Sonya
<b>Agroforestry is the answer predicted in Legal Mechanisms to the Brazilian Atlantic Forest and the Amazon Biomes Restoration</b> Deforestation in Brazil is an historical subject since the times of the colonization. The first Biome which felt the greed of exploitation, was the Atlantic Forest Biome. Wood, gold, diamonds and commodities, pressured this Forest. Nowadays less than 5% of its original cover still exists, suffering extensive pressure by the constant growth of the human society, because most of the population from Brazil lives in it. Nowadays the same is happening in another Biome regardless of the consequences: The Amazon Forest. At this moment, the Biome is being severally deforested. This work aimed to discuss if there are ways to revert this scenario	Meier, Martin Mancini Teixeira, Heitor Souza, Saulo Amaral, Jimi Marques, Henrique Miccolis, Andrew



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<p>through a systematic review of the Legal mechanisms existing in both Biomes: Atlantic Forest and Amazon, regarding to Deforestation, Ecological Restoration and Agroforestry. We observed that since the Eco 92 Conference the preoccupation about the environment was growing. Several important Legal marcs were written (Forest Code, Atlantic Forest Law, Conservation Units National System, Agroforestry regulations etc.) but the public policies to protect the environment shrank due to latest Government prioritizations, which declined financial support to the Sector responsible for controlling environmental crimes, in prevalence of economical issues, which enhanced Deforestation, as never seen before. Results show that both Biomes have several Laws, Decrees and Instructions, from the National, State and Municipality levels which gives substantial legal fundament to enhance the conservation of the Forests and the Restoration of Forest cover, including the use of Agroforestry Systems. We discuss that isn't due lack of regulation that Atlantic Forest and the Amazon are being deforested. Beyond legal mechanisms a great mobilization of the entire society is needed to learn that Agroforestry Restoration techniques may conciliate, "maintaining ecological functions", at the same time as produces income and food security for the people who broadly lives in those Biomes.</p>	
<p><b>Analysis of Livelihood Capitals to Support Peatland Agroforestry Development at Farm Level: Case from West Kalimantan, Indonesia</b></p> <p>Agroforestry offers potential solutions for sustainable livelihoods, as well as ecosystem service maintenance in peatland areas. It can contribute to increasing food security, reducing fire vulnerability and preventing biodiversity loss. Agroforestry, as a land-use system that integrates tree management in the farm, has been traditionally practiced by farmers. However, barriers in realizing the potential of agroforestry are diverse and numerous; evidence-based analysis is needed in identifying solution that suits local contexts. This study uses livelihood-capital approach to analyze barriers in agroforestry development and the solutions to overcome those barriers. We surveyed 27 villages in a peatland-dominated district, Kubu Raya, in West Kalimantan. The villages are located in nonforest zone, protection forests, and forest production areas. The study aims to unveil : (i) the variations of livelihood capitals across 27 villages and how they influence the potential of agroforestry-based livelihood development ; (ii) the relationships between livelihood capitals with the current policies and government programs that can set enabling conditions and overcome barriers ; (iii) potential interventions to promote agroforestry development for sustainable peatland management. We found that largely the livelihood capitals across 27 villages are similar. Human capital is the lowest among the five capitals, followed by natural, financial, social, and physical capitals. Lack of agroforestry extension services is the biggest barrier in developing agroforestry in the Kubu Raya peatland landscape. Fragile and poor natural resources also limit the number of agroforestry commodities that can be developed in the areas. There is also a lack of programs and policies targeting to promote agroforestry management in peatlands. Thus, to enhance agroforestry roles in sustainable peatland management, promoting agroforestry, particularly through technological access and capacity development, is needed. Integrating extension services into the overall sustainable peatland management system in Indonesia is the way to go.</p>	<p>Ferdyan, Dhio Teguh Martini, Endri Benita, Tania Dewi, Sonya</p>
<p><b>Would communities support agroforestry-based conservation of critical natural landscapes? Insights from a case of a watershed in Southern Philippines</b></p> <p>Natural landscapes provide various benefits that are critical for humanity's wellbeing and survival. However, human actions have been a major driver in the</p>	<p>Galang, Elson Ian Nyl Geetha, Mohan Vaughter, Philip Calub, Blesilda</p>



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<p>degradation of these critical natural landscapes as these are transformed into unsustainable land use practices to meet the dramatically rising demands in agriculture, commerce, and industry. Agroforestry offers strong potential as a conservation measure in these landscapes as its multifunctionality could maintain ecological functions (i.e., forestry component) while allowing communities to sustainably produce (i.e., agricultural component). It is under this purview that our study explores acceptability of agroforestry-based conservation of critical natural landscapes. We take the case of a watershed in Southern Philippines which serves as the only clean drinking water source among its surrounding towns while hosting several endemic biotas in the region. It has been under severe pressure due to rapidly expanding exploitive forms of agriculture and other extractive land uses. We measured acceptability among 108 randomly selected watershed-dependent residents using a proxy exercise that assesses their (1) knowledge on multifunctionality of agroforestry, (2) attitude to support agroforestry-based production, and (3) willingness-to-pay for incentivization of watershed direct managers (e.g., farmers) to implement and/or shift to agroforestry systems. Results show that knowledge on multifunctionality of agroforestry was high and attitude was generally supportive. In-depth interviews among residents indicated the value of integration of trees in farming. Only two-thirds, however, was willing to pay for incentivization. A statistically significant regression model shows that knowledge and supportiveness were not significant variables in explaining their willingness-to-pay but are heavily influenced by other socio-demographic variables (e.g., gender, age, years of education &amp; residence). While information dissemination on the benefits of agroforestry is important, these results tell that this should be coupled with more targeted policies that address the root causes on unwillingness to support agroforestry-based conservation of critical natural landscapes.</p>	
<h3>J. Which Agroforestry for Arid Climates?</h3>	
<p><b>What is the agronomic potential of a vine-tree association? Case study on traditional Bolivian agroforestry vineyards</b></p> <p>Agroforestry systems are increasingly being promoted to address the challenges of the agroecological transition that is coming. The crop biodiversity that they display provides many services which improve the environmental and economic sustainability of cropping systems. Nevertheless, some of these agroforestry systems have existed since ancient times. In Bolivia, in the Cintis, Paicho and Cotagaita valleys, viticulture is traditionally practiced in agroforestry systems, where vines (<i>Vitis vinifera</i>) are mostly grown together with "molles" (<i>Schinus molle</i>) that serve as tutors, and more rarely other species of trees including fruit trees. This example of agroforestry, is however little known. To capture the specificity of these unusual vineyards, we carried a descriptive socio-technical-economic study. Interviews were conducted with 30 farmers, and measurements were taken in plots to characterize their agroforestry management methods and expected ecosystem services. Performance varied significantly among the 30 farms, with yields ranging from 10 to 159 hL ha<sup>-1</sup> (average 47 hL ha<sup>-1</sup>), and turnover ranging from US\$ 460 to US\$ 9065 ha<sup>-1</sup> yr<sup>-1</sup> (average US\$ 2643 ha<sup>-1</sup> yr<sup>-1</sup>). Production costs range from US\$ 72 to US\$ 2406 ha<sup>-1</sup> yr<sup>-1</sup> (average US\$ 905 ha<sup>-1</sup> yr<sup>-1</sup>). The main services that farmers expected from this vine-tree association were protection against hail, improved vine yield and more effective control of</p>	<p>Oliva Oller, Pablo Notaro, Martin Langer, Erick Gary, Christian</p>

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diseases and pests. These performances are finally compared with more conventional vineyards in the South American region. Future studies must be carried out in situ to study the effective potential of these agroforestry vineyards in order to further assess the socio-economic performances and to measure the agroecological benefits of this original vine-tree association.	
<p><b>Assessing the performance of an agroforestry system (AFS) based on Quinoa (<i>Chenopodium quinoa</i> Willd) and Olive tree (<i>Olea europaea</i>) under saline conditions in Eastern Morocco</b></p> <p>Agricultural productivity, especially in semi-arid areas, faces serious challenges and climate change tops the list. Indeed, it exacerbates water scarcity, soil degradation and its perpetual salinization. Consequently, looking for sustainable and resilient cropping systems is a forefront priority for the National strategy « Green Generation 2020-2030 ». Currently, agroforestry systems could be a sustainable way to diversify and improve land productivity thanks to their potential complementarity and facilitation. However, trees could also compete with crops for natural resources such as water, nutrients and light. In this context, this study aims to introduce and adapt quinoa as a halophyte crop to diversify and improve current intercropping systems performance. A field experiment was laid out in a randomized complete block design with two cropping systems: Sole cropping (SC) and intercropping systems (AFS), four quinoa cultivars (Puno, Titicaca, ICBA-Q5 and ICBA-Q4) and olive orchard alone as a control (OR) in each block. The experiment was conducted on an organic farm under drip irrigation with saline water (4 g/l). The main objectives consisted on assessing the Land Equivalent Ratio (LER) and comparing the quinoa cultivars and olive yields in each cropping system. Yield comparison of the four quinoa cultivars in both sole and intercropping systems showed yield's superiority for all varieties when they are intercropped with olive trees. Titicaca achieved the best yield increase (41%). Simultaneously, olive trees yields were improved in AFS relatively to olive orchard (OR) and best result was recorded with ICBA-Q5 variety (52%). Furthermore, LER is always greater than one regardless of quinoa variety. This result demonstrate the high performance of agroforestry system based on quinoa and olive tree under saline irrigation in Eastern Morocco.</p>	<p>Abidi, Ilham Alaoui, Si Bennasser Daoui, Khalid Bazile, Didier Mahyou, Hamid Gaboun, Fatima</p>
<p><b>Canopy management of scattered <i>Prosopis cineraria</i> (L.) trees for sustainable fodder production in agricultural landscape of arid and semi-arid regions</b></p> <p>The experiment was carried out on <i>Prosopis cineraria</i> (L.) trees scattered in the agriculture land scape of Agricultural Research Station, Keshwana, Jalore, Rajasthan. Aim was to standardise the lopping intensity for different girth class of trees for sustainable fodder production.. Fresh and dry fodder weight was higher in T1 (100 %) than T2 and T3. Among girth class treatment the sequence was G3 &gt; G2 and G1. The combination T1G1 resulted in significantly higher fresh and dry fodder yield for both the year. Such interaction was observed for the combination T1G3 and for T2G2 combination. Percent increase in fresh fodder yield T2G2 combination had highest i.e. 46 %, highest dry fodder yield was observed in combination in T1G1 (35 %). There is increased inclination in carrying capacity, in T1 (0.38), G3 (0.59), and T1G1 (0.12), T1G3 (0.84) and T2G2 (0.19) combinations which supported 61.61, 94.96, 19.13, 136.04 and 31.57 no. of goats ha-1. There is a significant increase in the feed capacity, higher increase was observed for G3 along with T1 &amp; T2 combination. For girth class G2 with T2 &amp; T1 was found to be 9.02 No. ha-1 for 2018-20. Girth class G1 with lopping intensity T1 combination was 6.98 &amp; 3.63 No. ha-1 respectively. Dry fodder yield had significant positive correlation with fresh fodder weight, percent change in fresh fodder weight,</p>	<p>N V, Sares Godara, Asu Singh Meena, Dharmendra Arjun Lal, Bijarnia Kumar, Dileep</p>

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percent change in dry fodder production, and fodder feed capacity and significant negative correlation for crown width. It is concluded that for girth class G2-medium and for G1 & G3- heavy intensity lopping should be adopted for higher fodder production, carrying capacity, feeding capacity in <i>Prosopis cineraria</i> trees existing in the scattered agricultural landscape of arid and semi-arid regions.	
<p><b>Effect of fertility levels on growth, yield and quality of sesame (<i>Sesamum indicum</i> L.) varieties under custard apple (<i>Annona squamosa</i> L.) based agroforestry system</b></p> <p>Sesame (<i>Sesamum indicum</i> L.) is an important edible oilseed crop grown in India. India ranks first, both in area and production of sesame in the world, but the productivity is lower than its potential because of poor cultivation, use of inferior varieties, improper fertilization and management in sub-marginal and marginal lands where there is deficiency of nutrients. Keeping this information into consideration, the present investigation was conducted to study the response of three improved sesame varieties ('Shekhar', 'RT-346' and 'Type-4') with application of three fertility levels (20,10,10,10 N, P2O5, K2O &amp; S ha-1, 40,20,20,20 N, P2O5, K2O &amp; S ha-1 and 60,30,30,30 N, P2O5, K2O &amp; S ha-1) under custard apple (<i>Annona squamosa</i> L.) based agroforestry system. The field experiment was laid out in Split-plot design having 9 treatment combinations (i.e., 3 fertility levels × 3 varieties) during Kharif, 2018-19 at the research Farm, Banaras Hindu University, Uttar Pradesh (India) under rainfed condition. Findings of the study revealed that variety 'Shekhar' recorded more number of branches plant-1, capsules plant-1, dry matter plant-1, 1000 seed weight and higher seed yield than the variety 'RT-346' and 'Type-4'. Among all fertility levels, application of 60,30,30,30 N, P2O5, K2O &amp; S ha-1 produced significantly higher seed yield (675 kg ha-1) as compared to 40,20,20,20 N, P2O5, K2O &amp; S ha-1 and 20,10,10,10 N, P2O5, K2O, &amp; S ha-1. Similarly, the maximum net returns (Rs 31622) and benefit cost ratio (1.94) were also recorded in 60,30,30,30 N, P2O5, K2O &amp; S ha-1 with variety 'Shekhar'. At higher fertility levels, there is greater availability of nutrients which further leads to higher growth and yield. It may be concluded from the present study that variety 'Shekhar' and fertility level of 60,30,30,30 N, P2O5, K2O &amp; S ha-1 may be suitable for higher growth and productivity of sesame under agroforestry system in rainfed condition.</p>	Kumar Singh, Alok Dipriya Minz, Srishti
<p><b>Local preferences for three indigenous oilseed plants and attitudes towards their conservation in the Kénédougou province of Burkina Faso, West-Africa</b></p> <p>Background: <i>Carapa procera</i>, <i>Lophira lanceolata</i>, and <i>Pentadesma butyracea</i> are three underutilized but increasingly threatened indigenous oil-seed tree species (IOS) in tropical Africa. Objective: To investigate the socio-economic factors that explain local people's (i) preferences for these IOS, (ii) attitudes toward their conservation, and (iii) ability to identify "plus trees" based on seed traits. Methods: 336 informants from 14 randomly selected villages in the species distribution area of Kénédougou province were interviewed about the number of actual uses reported, practiced conservation actions, and possible criteria for selecting preferred trees for seed oil extraction. Results: The results showed species-specific patterns. <i>Carapa procera</i> had the highest UV and hence was the most preferred IOS. The most cited conservation actions were assisted natural regeneration and banning of tree cutting, which were practiced for <i>C. procera</i> and <i>L. lanceolata</i>. No conservation measure was cited for <i>P. butyracea</i>. Tree selection for oil-seed collection was mainly guided not by "oil extraction yield" but rather by the "quality of extracted oil" (namely oil color and taste for food uses, and oil bitterness for medicinal efficacy). The selection mainly concerned <i>L. lanceolata</i>.</p>	Tietiambou, Fanta Reine Salako, Valère Kolawolé Tohoun, Jésuskégo Roméo Ouedraogo, Amadé

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<p>Discussion : The preference for <i>C. procera</i>, positively correlated with its conservation attitudes, suggests that it probably has a better potential to improve the livelihoods of local communities than the other two IOS. This was consistent with our prediction that species with higher actual UV receive better conservation actions from users in order to ensure their long-term usage and benefits. The preference based on oil quality can be explained by the fact that oils of the studied IOS are commonly used in cosmetics and human food and often in association with shea butter. Conclusion: This study provided useful local knowledge-based information to guide conservation actions and valorization strategies of three IOS.</p>	
<p><b>Budded <i>Prosopis cineraria</i>-based agroforestry system for earlier and higher yield in western arid Rajasthan, India</b></p> <p>Background. Budded <i>Prosopis cineraria</i> is early pod bearing (high value for dehydrated pods) species deliver economic returns in three years after planting which non-budded tree yield after 10-12 years. It is developed through budding technique from thornless, high and better yielding <i>P. cineraria</i> germplasm. Objectives. Being an important component of agroforestry systems of Western arid Rajasthan budded <i>P. cineraria</i> is gaining high popularity among farmers due to its early yield potential. Therefore, the study compared the growth and yield attributes of budded and non-budded <i>P. cineraria</i> in agroforestry system. Methods. Non-budded (control) and budded <i>P. cineraria</i> (6m x 6m, 6m x 9m and 6m x 12m spacing) were planted in the field. Pearl millet and green gram crops were grown in Kharif season. Tree growth parameters were recorded for both systems. Results. No significant differences for tree height were recorded among three years old budded and non-budded trees whereas, collar diameter and fodder yield varied significantly. Tree height ranged between 1.2 m (control) to 1.8 m (6x6m spacing of budded trees) and collar diameter 8.9 cm (control) to 17.2 cm (6x9m spacing). Formation of pods started after three years in budded trees while no pod formation was recorded in non-budded trees. Pod yield was maximum in 6x6m spacing budded trees i.e. 624±42.1 g tree<sup>-1</sup>. Fodder yield from trees showed significant differences among budded and non-budded trees with maximum yield of 2.05 kg tree<sup>-1</sup> (6x6m spacing of budded trees) and minimum of 0.64 kg tree<sup>-1</sup> (control). Discussion and conclusion. The growth and biomass production was significantly higher in budded <i>P. cineraria</i> compared to non-budded though there were no significant differences in different spacings. It is concluded that system yield of budded <i>P. cineraria</i> based agroforestry system was much more compared to non-budded one after three years of establishment.</p>	<p>Verma, Archana K, Shiran Tanwar, Sps Pareek, Kamlesh</p>
<p><b>Woody stems and leaves to improve soil faunal activity and nutrient cycling in cropping systems!</b></p> <p>Agroecological practices are emerging as efficient alternatives to address the challenge of sustainable agriculture. The objective of this study was to examine whether plant residue amendments from stems and leaves (SL) of an agroforestry shrub (<i>Piliostigma reticulatum</i>) enriched with nitrogen (N) sources improve nutrient cycling in Soudano-Sahelian cropping systems. The experimental design was organized into four replicates with six treatments consisting of two treatments of SL residue amendments (amended and non-amended) in combination with three treatments including additional N sources (natural soils, urea, and cowpea as intercrop). The results showed that the activity of termites (<i>Nasutitermes torquatus</i>) and ants (<i>Messor galla</i> and <i>Pachycondyla rufipes</i>) was 12–13 and 2–3 times higher in the SL amended soils than in non-amended soils, respectively. The activity of earthworms (<i>Millsonia inermis</i>) was highest in the SL amended soils associated with the cowpea intercrop, and was significantly lower</p>	<p>Guebre, Daouda Traoré, Salifou Hien, Edmond</p>

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<p>in the urea enriched soils. SL amendments and N enrichments had no effect on soil basal respiration. The substrate-induced respiration with N substrates (L-alanine and L-arginine) was 25 and 52 % higher in the SL amended soils than in the natural soils without any N inputs, indicating N limitation of microbial activity. This corroborates the higher C/N ratio (14.3) observed in the SL amended soils compared to the natural soils without any inputs (10.3). The N enrichment decreased the C/N ratio of the SL amended soils but was not efficient to alleviate microbial catabolic limitations, likely by switching from N to C limitation. Overall, the SL amendments with or without N enrichments triggered temporarily the soil macrofaunal activity, increased the NH<sub>4</sub>-N availability compared to that of NO<sub>3</sub>-N, and improved crop performance.</p>	
<p><b>HYDRUS Modeling of Sahelian Agroforestry Ecosystem: An investigation of local water balance</b></p> <p>Agricultural productivity in the West-African Sahel is dependent on the climate and is strongly affected by periods of drought due to the rainfed nature of farming in the area. The agroforestry practice of intercropping a native shrub species (<i>Piliostigma reticulatum</i>) with drought resistant crops of groundnut (<i>Arachis hypogea</i>) and pearl millet (<i>Penisetum glaucum</i>) has been shown to retain more moisture within the soil column than crops grown alone. Yields of intercropped plots have also been increased by over 100% compared to controls. This study will investigate water-soil-plant-atmospheric interactions by calibrating a hydrologic model using soil moisture and meteorological data collected between 2012-2015 from Niore du Rip, Senegal. HYDRUS 1D software will be used to model the water balance under varying climatic conditions. Based on the field data, the soil moisture storage increased in the agricultural plots that had the native shrubs intercropped (overall mean of 0.12 cm and maximum of 0.18 cm) over the three-meter profile, especially during times of no rainfall, whereas the plots with staple crops (mean of 0.11 cm) or no crops at all (mean of 0.11 cm), showed decreased water storage during these times. The modeled potential evapotranspiration (ET) indicated that the Sahel, being a semi-arid region, had high climatic demands of 9.64 mm day<sup>-1</sup> during the seasonal rains, but decreased to 3.66 mm day<sup>-1</sup> during dry periods. This model will allow us to predict how much water would likely percolate below the zone containing the majority of the shrub and crop roots (3m) and into groundwater under a variety of rainfall conditions. We expect this work to inform recommendations about the optimal planting density of the native shrubs to gain the yield benefits of shrub intercropping while maintaining the <b>integrity and sustainability of the soil and groundwater supply in the region.</b></p>	Lushbough, Nicole
<p><b>Productivity and carbon stock of different land-use systems of Leh region of Himalayan cold desert</b></p> <p>A cold desert ecosystem refers to an area where the climate has characteristics of great extremes of being hot and cold combined with excessive dryness. The temperature in these tracts normally ranges from -45° C during winters to +35°C in summers. Ladakh forms a part of cold desert which comes under trans-Himalayan zone of India. The whole area is an arid region devoid of vegetation and is not benefitted by the south east monsoon; which is the main source of rainfall in India, as it lies in the rain shadow area of the Himalayan mountain system. The soil of the region is generally poor in nutrient availability because of less addition of organic matter into the soil. There is very less data available about the productivity and carbon storage potential of different land use systems of this region. Therefore, a study was conducted to calculate the total productivity and carbon stock of different land use systems found in the region during the years</p>	Namgial, Jigmet Prabhakar, Mukesh Prabhakar, Mukesh Gupta, Sushil Rathore, Gitanjali



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<p>2017-2018. The study was carried out in two blocks of Leh district, selected using random sampling method in the erstwhile state of J&amp;K, India. A total of 7 (treatments) land use systems viz. Agriculture, Horticulture, Agrisilviculture, Agrihorticulture, Agrihortisilviculture, Silvipasture and Hortisilvipasture were analysed. The same treatments were analysed in 4 villages (Replications) from each block. The maximum total biomass production was recorded in hortisilvipasture (30.88 t ha<sup>-1</sup>) and minimum in agriculture (8.76 t ha<sup>-1</sup>) land-use system. The maximum total carbon stock was recorded in hortisilvipasture (15.44 t ha<sup>-1</sup>) and minimum in agriculture (4.38 t ha<sup>-1</sup>) land use system. The studied concluded that agroforestry systems are more productive than monocropping systems such as agriculture and horticulture.</p>	
<p><b>Assessment of soil organic carbon stocks under arid land agroforestry systems</b>  Arid lands are tremendously variable concerning land arrangements and fauna, flora, soil structures, water balance, and human occupations. The core element, "aridity", indicates the dryness of the zone with the low and uncertain rainfall. In addition, tremendous whirlwinds and solar systems surge the effect of rainfall uncertainty. The all-composite generates a fragile ecosystem in which little agitations may produce a high loss to sustainability, sometimes irrevocable. The increase in atmospheric carbon dioxide (CO<sub>2</sub>) concentrations caused by fossil fuel combustion emissions contributed to current climate change, one of the world's greatest challenges and paused a severe threat to the already fragile arid environment. Agroforestry systems (AFS) can help to limit such increases and, as a result, contribute to climate change mitigation. Agroforestry refers to the practice of producing crops, livestock, and tree biomass on the same plot of land. The soil organic carbon (SOC) pool, in particular, is the sole terrestrial pool that has been accumulating some carbon (C) for millennia and may be intentionally increased by agroforestry methods. The objective was to quantify the SOC storage under arid land AFS compared to treeless farmlands at two different depths (0-5 and 5-10 cm). SOC was determined by dry combustion. The SOC stock in a depth between 0-10 cm was significantly high in AFS and farmland (<math>p &lt; 0.0001</math>). In the surface layers of soil, there were no significant differences in the SOC stock. However, below 5 cm, the AFS had a large SOC stock with 0.42 Mg C ha<sup>-1</sup>y<sup>-1</sup> than the farmland 0.22 Mg C ha<sup>-1</sup>y<sup>-1</sup>. Overall, this study showed the potential of AFS to store C in both soils in arid regions, and it indicated that the AFS is efficient in sequestering SOC. This result can play an important role while selecting different land-use systems for effective climate mitigation.</p>	Kouyate, Diakalidia
<p><b>Integrating <i>Gliricidia sepium</i> and Chololo pits enhances resilience of maize-based cropping systems in semiarid Tanzania</b>  Shifting of rainfall patterns and seasons adversely affect the resilience of farming systems in semiarid areas. Resilient agricultural (RA) practices such as agroforestry and rainwater harvesting are promoted to mitigate such effects and sustain crop production. However, these practices are studies separately and no information on their synergies under planting window options in semiarid areas. To fill this gap, we assessed the effects of integrating agroforestry and rainwater harvesting (Chololo pits or planting basins) under different planting windows on soil moisture and maize grain yield in Kongwa District, Dodoma, Tanzania. A factorial experiment was adopted to test the effects of planting window (Early, Normal and Late planting), and CSA practices (Maize monoculture, <i>Gliricidia sepium</i> intercropping and Intercropping with <i>G. sepium</i> and Chololo pits). The planting windows were determined based on previous studies and national weather forecasts as Mid-November to Mid-December (Early), Mid-December to Mid-</p>	Kimaro, Anthony Lingilie, Abdala Shirima, Deo



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January (Normal) and Mid-January to Mid-February (Late). Results revealed that soil moisture content, maize growth and yield varied significantly between planting windows and RA practices. The G. sepium-Chololo pits treatment increased soil moisture by 43% compared to 35% and 25% in G. sepium and maize monoculture treatments, respectively. Overall, G. sepium intercropping alone increased maize grain yield by 23% relative to monoculture (2.6t/ha) due to improved soil fertility. Maize grain was the highest (2.8-4.2t/ha) in the G. sepium-chololo pits treatment across all planting windows, reflecting stable yields due to the combined effects of improved soil fertility and soil moisture. Higher maize yields at normal planting in all RA practice affirms that this is the appropriate planting window for Kongwa. Apparently, combined use of weather information on the appropriate planting window and RA practice improve yields and build resilience of maize-based farming systems in semiarid areas.	
<b>Can rainfed <i>Dendrocalamus stocksii</i> based agroforestry be a smart choice for the semi-arid agroclimatic regions? A case study from India</b> Sustainable bamboo agroforestry management can help to alleviate the consequences of poverty and environmental deterioration. To build a sustainable agroforestry model, several bamboo-based agroforestry combinations should be tested. An experiment was carried out in a moist semi-arid agro-climatic region of India in <i>D. stocksii</i> plantations at two different spacings, 5 m X 5 m and 9 m X 9 m, were selected for the experiment. <i>D.stocksii</i> is well suited in agro-forestry systems owing to its morphological characteristics. The experiment was laid in a randomized block design. Three intercrops were chosen for bamboo-based intercropping. This experiment was done during consecutive years. The result was a crop failure in terms of yield for all the years. To explain crop failure and to explain the resource sharing follow-up studies like fertility analysis and water holding capacity were also taken up. Spiral trench method was also done to study the rooting pattern of bamboo in both the spacings. Majority of roots (>95 %) belonged to less than 2 mm (fine root) diameter class. Total number of roots was found higher in 9 m X 9 m spacing. The results of this experiment indicate that the semi-arid agro climatic conditions of Karnataka will not permit the rainfed intercropping of twelve-year-old <i>D. stocksii</i> plantations. The semi-arid agro climatic conditions of Karnataka may permit intercropping of <i>D. stocksii</i> if we can provide irrigation at least during critical periods. A sustainable agro-forestry system should have a combination of trees and plants of divergent root growth habitats. Identifying the spatial distribution of competitive zone is essential for the meticulous planning of bamboo-based agroforestry systems.	P A, Lubina K.S, Dr Anil Kumar Viswanath, Dr. Syam
<h3>K. Which Agroforestry for Annual Crops?</h3>	
<b>Walnut pollards: a win-win-win solution for temperate alley-cropping systems?</b> Grafted walnut trees for nuts are included in many traditional agroforestry systems, while ungrafted and hybrid walnut trees are also cultivated for their high quality timber in modern agroforestry schemes. Walnut trees are highly compatible with winter crops: their deep rooting pattern and very late budburst in Spring reduce both water and light competition with winter crops. However, mature walnut trees are large trees, and overcast dense shade on underlying crops, resulting in low crop yields when the canopies cover the whole plot. Pollarding is a very traditional tree management option that was mostly applied to oaks, mulberry or ash trees in France to produce fodder for ruminants or	Dufour, Lydie Bourdoncle, Jean-François Sellier, Alain Gosme, Marie Le Bec, Jimmy André, Jérémy Dupraz, Christian

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<p>silkworms. No record of traditional walnut pollards can be found in France. We set up a walnut pollarding experiment in 2013 at the Restinclières agroforestry Estate in Southern France to assess if walnut trees can cope with pollarding, and to measure the trade-offs between timber increment, branch biomass production and crop yield. Fifty trees were pollarded in 2013, 2017 and 2021 and the harvested branch biomass was measured. During the growing season, the trunk diameter growth was bimonthly monitored with microdendrometers from 2014 to 2021 on all the pollarded trees and on non pollarded control walnut trees. Crop yield was monitored in sole crop control, under non pollarded trees and under pollarded trees for several cropping seasons. Walnut trees reacted very vigorously to pollarding, with branches reaching a diameter of 15 cm after five years. Pollarding did reduce timber increment in the trunk during the first two or three growing seasons after pollarding, but not during the following growing seasons. The second pollarding induced a higher reduction in trunk girth growth than the first one (figure 1). Crop yield was highly stimulated after pollarding during 2 or 3 years. Pollarding walnut trees is an option to maintain a medium size for tree canopies. This allows to keep more trees per hectare (up to 200) than growing standards (50 trees/ha). However, the harvest of branches for chipwood is job demanding, and timber quality and quantity is decreased by pollarding. The highest biomass production was achieved by alley-cropping with pollards, but the optimum scheme for farmer's income will depend on the relative commercial values of timber, chipwood and crops.</p>	
<p><b>Agroforestry improves the benefits of cereal-legume intercropping under drought</b></p> <p>The benefits of cereal-legume intercropping are promising under non-limiting water conditions due to the high resource-use complementarity between the species. The positive effects are interesting to improve yields in zero-input organic agriculture. However, the balance of plant-plant interactions may shift depending on the environmental conditions. Cereals and legumes may compete more intensively for water and nutrients under drought, making yield decline in intercropping. In this study, I asked whether agroforestry could recover or boost the benefits of cereal-legume intercropping in drought-prone areas. I hypothesized that shading trees create beneficial conditions that could alleviate the negative impacts of drought on plant-plant interactions. To test the hypothesis, I conducted a two-year field trial on two different sites with contrasting levels of aridity during the growing season, respectively in the North (France, 337 mm, the 'wet site') and the South (Morocco, 150 mm, the 'dry site') Mediterranean. I compared two cereal (barley and durum wheat) and legume (faba bean and chickpea) species in monoculture versus in mixture, in full conditions versus in agroforestry with olive trees following a split-plot design. The trials were managed with zero-input organic practices to better detect the shift in plant-plant interactions between sites and mixtures. I found that drought negatively impacted biomass production but not yields across sites. In general, cereal-legume mixtures were effective (+ 45 % of yield), especially at the 'dry site'. Cereals (+ 37 %) more than legumes (+ 8 %) benefited from intercropping. Despite reduced crop yields (- 60 % on average), agroforestry improved (wheat-legume mixtures) or at least had no effect (barley-legume mixtures) at the dry site, while it negatively impacted all the cereal-legume mixtures at the 'wet site' (- 20 %). The results show that trees can positively modify the outcome of plant-plant interactions underlying the benefits of intercropping under increasing drought.</p>	Barkaoui, Karim

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<p><b>Evaluation of agronomic performance of legumes in an agroforestry system based on olive trees in the south of the Mediterranean</b></p> <p>In olive tree-based agroforestry, trees compete with crops for soil resources, but they can also improve crops growing conditions under drought conditions, mainly by providing shade during the growing season. Olive trees provide permanent shade for intercrops with different intensity depending on the season and the orientation of sowing intercrops. In this study, we evaluated three legumes (faba bean, chickpea and lentil) in olive agroforestry in northern Morocco. We compared growths in sole crop or intercrop legumes to examine aboveground competitive interactions and pinpoint the likely response mechanisms. We assessed the effect of shade and distance from trees on crop growth, yield components, and final yields. Plant height, aboveground biomass, and grain yield were all higher in 2016 than 2017, and lower in Agroforestry than sole crop for all the legume species. In average, faba bean had the tallest plants (74.33 cm), the highest biomass (32.30 g.m-2) and yield (17.23 g.m-2), while lentil had the shortest plants (32 cm) and the lowest biomass (13.80 g.m-2) and yield (1.18 g.m-2) amongst the three species. Under olive trees, faba bean grain yield was highest under non-Shaded conditions and declined with increased shade, while lentil recorded the highest yield under the shade, and for chickpea the distance from the trees had no effect on the final grain yield. The number of pods and grains per unit area was the most impacted yield component in both 2016 and 2017. Olive trees limited crop growth and caused a significant reduction in grain yield, whatever in 2016 under drought, olive shade had a significant impact on grain number per unit area and grain yield. Despite lower crop yields, We show how shade may impact the performance of legumes under olive Agroforestry.</p>	<p>Amassaghrou, Asmae Barkaoui, Karim Bouaziz, Ahmed Daoui, Khalid</p>
<p><b>Wood production in agroforestry systems for sustainable energy use</b></p> <p>The above-ground biomass yield of seven multi-purpose tree species (MPTS) viz. <i>Acacia auriculiformis</i>, <i>Albizia moluccana</i>, <i>Bauhinia purpurea</i>, <i>Ficus auriculata</i>, <i>Michelia oblonga</i>, <i>Robinia pseudoacacia</i>, and <i>Symingtonia populnea</i> at seven years of age were assessed in an agroforestry plantation at Barapani, Meghalaya, India. The inter-row spaces of MPTS stand were utilized for growing crops viz. maize, blackgram, Bengal gram, cauliflower, pea, soyabean, french bean, and groundnut, and the crop yields were monitored in the first six years of tree growth. Various physico-chemical properties of wood such as moisture content, ash content, density, silica, nitrogen, volatile matter and fixed carbon content were determined. The gross heat of combustion was determined in a bomb calorimeter. Fuel Value Index (FVI) of the wood samples of each of the tree species was calculated considering density and calorific value as positive character and ash content as negative character. Total biomass and stand biomass were calculated by taking into consideration the bole, branch and twigs. <i>A. auriculiformis</i> yielded the highest biomass followed by <i>R. pseudoacacia</i> and <i>M. oblonga</i>. FVI was found to be the highest in <i>M. oblonga</i> followed by <i>A. moluccana</i> and <i>A. auriculiformis</i>. Six parameters viz., moisture content, silica content, nitrogen content, fixed carbon, FVI and effective biomass which reflect combined characteristics of combustion and biomass productivity were considered for deriving an index - energy performance index (EPI) for ranking the seven MPTS in the following order of <i>M. oblonga</i> &gt; <i>A. auriculiformis</i> &gt; <i>A. moluccana</i> &gt; <i>R. pseudoacacia</i> &gt; <i>B. purpurea</i> &gt; <i>S. populnea</i> &gt; <i>F. auriculata</i>. Yield of crops in the agri-silviculture was lower than the average yield of crops in the study area and it further decreased in the successive years of plantation. The present study showed groundnut, cauliflower and soyabean as suitable crops for inclusion in agro-forestry systems in the study area.</p>	<p>Kataki, Rupam</p>

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<p><b>Cereal production in alley cropping systems</b></p> <p>There are about 700 000 hectares of agricultural land in Hungary with marginal site conditions, where financially viable production is not possible in the conventional way. On such sites, introducing trees may lead to more productive farming, but it is crucial to have some data on the yield of the intercrop, to be able to compare it to the conventional farming practice. In this study the yield of the intercrop is presented. The measurements took place in Gödöll' in an alley cropping experimental site characterized by Arenosol, where triticale (x Triticosecale) was grown in between rows of black locust (<i>Robinia pseudoacacia</i> L.). The rows were 9, 15 or 21 meter wide, and the in-row spacings were 1, 2 or 3 meter, resulting in nine different treatments (9 x 1, etc.), plus the control plot of the triticale without trees. The harvests were in 2018 and 2019, when the trees were 4 and 5 years old, respectively. The yields were analyzed on a g/m<sup>2</sup> basis in order to exclude the affect of the reduced sowing area, caused by the presence of the trees. In both of the years, the 15 x 2 treatments yielded the highest, which were also significantly higher than the control. In 2018 there was no other statistical difference between the control and the treatments. In 2019 some yields of the treatments were significantly higher than the control, but no statistically lower yields were observed, although the control plot was located in a poorer site in that year. Overall, the presence of trees did not decrease the yields compared to the control, and it is possible that the higher yields in some cases can be attributed to them. It could also have been affected by the soil, the weather, or due to biodiversity aspects, if not all combined.</p>	<p>Honfy, Veronika Pödör, Zoltán Keser', Zsolt Borovics, Attila</p>
<p><b>Long-term effects of <i>Piliostigma reticulatum</i> (DC) Hochst densities on soil water status and carbon stock in Burkina Faso's northern Sudanian</b></p> <p>Agroforestry parklands have an important role in water dynamics and soil carbon storage. However, in farmer's fields, no established rule for the distribution of woody species in the fields exists, and a degeneration of agroforestry parklands has been observed. In order to provide a better management of these parklands, it is essential to evaluate the effects of shrubs on water and soil carbon storage dynamics. This study aimed to present the effect of different densities of <i>Piliostigma reticulatum</i> on the soil water storage capacity (SWS) and the carbon stock within 0-10 cm soil layer, eight years after the implementation of a trial at Kamboinse in the northern Sudanian zone of Burkina Faso. The experimental design was a Fisher block with eight treatments and four replications, with two types of tillage (zaï and no-till). The zaï had four shrubs densities (0, 500, 1000 and 2000 shrubs/ha) and no-till had three densities (0, 500 and 2000 shrubs/ha). Overall, the SWS and carbon stock increased with shrubs density. They were higher at 2000 shrubs/ha in zaï, with values of <math>18.14 \pm 1.50</math> mm and <math>5.62 \pm 0.39</math> t/ha respectively, and lower in the no-till (control) with <math>10.67 \pm 2.66</math> mm (p-value = 0.00663) and <math>4.39 \pm 0.32</math> t/ha (p-value = 0.0315) respectively. SWS values were similar for the different shrubs densities of 500, 1000 and 2000 (in zaï), and for the densities of 500 and 2000 (no-till). On the other hand, the shrubs density of 2000 significantly increased the carbon stock compared to the densities of 500 and 1000 in zaï and no-till. We concluded that density could therefore favor biological functions than improvement of the soil water status of northern Sudanian zone soils.</p>	<p>Coulibaly, Kalifa Barro, Moussa Douzet, Jean-Marie Cournac, Laurent Nacro, Hassan Bismarck Gnissien, Moussa</p>

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<p><b>Effect of organo-mineral fertilization on soils characteristics and cotton and maize yields in a rotation within hedgerow production system with <i>Leucaena leucocephala</i> (Lam.) de Wit in the subhumid zone of Mali-sud</b></p> <p>There is a progressive decrease of agricultural production in Mali and elsewhere due to some challenges faced by cropping soils. These challenges include demographic pression, loss of vegetal cover and soil fertility amongst others. To overcome these constraints, SustainSahel project has started in 2021/2022 experimentation about the hedgerow production system with <i>Leucaena leucocephala</i> in association with cotton and maize in rotation in the Agronomic Research Station of Farako in Sikasso for tree production campaigns. The RCBD design in split-plots was used to set up the experiment. The main factor is cropping system with <i>L. leucocephala</i> (AL) and without <i>L. leucocephala</i> (SL); While the second factor is made of 6 level of fertilization (F1= without fertilizer, F2= Organic manure recommended (OM) 5 t/ha, F3= mineral fertilizer recommended (MFR), F4= OM + ½ MFR, F5= ½ MFR + Chaux 500 kg/ha, F6= ½ MFR + PNT 300 kg/ha). During the first year, <i>L. leucocephala</i> was planted; the sowing of cotton and maize will be done in second and third year. Data collection will be about: Soil: sampling will be done to characterize the bio-physico-chemical properties of soils before, during and after the set up. <i>Leucaena leucocephala</i>: plant height and diameter will be recorded at each two months one year after the planting plus the survival rate at the end of each cropping season. <i>L. leucocephala</i> biomass will be weighted and incorporated to the soil. Cotton: height and stem diameter will be taken at 60e, 75e, 90e and 105e JAS; yield and nutrient migration index. Maize: height and stem diameter will be taken at 3e, 5e, 7e, 9e Week after emergence (WAE). Yield and nutrient migration index. Collected data will be analyzed by using SAS software version 9.3. The results generated will contribute to improve soils fertility and cotton and maize yields in an integrated system of trees, crops and animals in the Sahel.</p>	<p>Macalou, Salouma</p>
<p>L. Which Agroforestry for Commercial Perennial Crops and Trees?</p>	
<p><b>High resolution suitability mapping to assess the potential for agroforestry in the US Midwest</b></p> <p>Agroforestry has the potential to help address a variety of socio-economic and ecological problems plaguing the world, especially in places where it is currently underutilized. This is particularly true in the US Midwest, where annual corn and soybean production is the dominant land-use. To increase agroforestry adoption, it is important to identify where agroforestry is likely to succeed. Here we use tree crop suitability maps to map and assess the potential for agroforestry in the US Midwest. We created tree crop suitability maps for 15 promising agroforestry species in the region using a rules-based approach based on environmental suitability criteria created following extensive literature searches and expert review. To identify areas suitable for agroforestry, we combined suitability maps for several woody crops, thereby assessing the overall potential for agroforestry at different suitability levels (suitable vs. ideal based on a calculated suitability index). To identify where tree crops may be economically competitive with traditional commodity crop production, we compared tree crop suitability scores with commodity crop production indices. Preliminary results indicate that over 80% of agricultural land in the US Midwest is suitable for at least one tree crop species. Some species are suitable across broad areas while others are confined to smaller areas, though the latter can be relatively complementary in their</p>	<p>Shea, Monika Kreitzman, Maayan Wolz, Kevin</p>

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<p>suitability. Many species have high suitability in areas that are highly suitable for commodity crop production, though they are also suitable in more marginal areas, suggesting that agroforestry adoption efforts should focus on both marginal and productive land. We discuss varying suitability patterns and their limitations for different parts of the region. Overall, the potential for agroforestry is high in the US Midwest. High resolution mapping can help identify areas to focus agroforestry adoption efforts.</p>	
<p><b>Development of a sweetfern (<i>Comptonia peregrina</i>) crop for the production of essential oil in Northern Québec</b></p> <p>BoreA Canada is a business located in Northern Québec specializing in the production of organic boreal essential oils based on a circular economy model. Their products are marketed across the globe. They distill their oils using residual steam recovered from a cogeneration plant that generates electricity through the combustion of logging residue biomass. BoreA Canada tasked Biopterre, an applied research centre, with assisting them in diversifying their product offering. The project mainly focused on developing a new essential oil from sweetfern (<i>Comptonia peregrina</i>) through the implementation of a successful model for establishing and growing this crop that harnesses the value of local resources and industrial coproducts. The project also aimed to compare differences in yield and essential oil composition in natural populations. Various parameters for producing plants in a greenhouse and establishing them in the field were studied (crop substrates, rooted plants versus rhizomes, soil texture, etc.). Variations in essential oil yield and in their level of different aromatic molecules were compared using GC MS for 3 sites on 3 harvest dates. The results of the greenhouse propagation are conclusive. Using a growing medium comprised of peat ash appears to be the most beneficial in terms of both productivity and economics. When established in the field, rooted plants produced considerably better results compared to propagation using rhizome segments. Soil texture was a limiting factor for the establishment of rhizomes. The yield and aromatic molecule content of the essential oil varied significantly depending on harvest date and site. <math>\beta</math>-caryophyllene is a molecule of interest that fluctuated based on these parameters. These results have encouraged BoreA Canada to continue their research.</p>	<p>Nadeau, Isabelle Laroche, Lucie</p>
<p><b>Local effect of two leguminous trees species on total carbon stock and litter quality in a cocoa-based agroforestry system</b></p> <p>Cocoa farming in Côte d'Ivoire is traditionally practiced in full sun mode. However, cocoa-based agroforestry systems are explored as adaptation and mitigation solutions for cocoa production more particularly in term of carbon sequestration. Based on the results of a 20-year experiment, we assessed the impact of associated trees (AssT), <i>Albizia lebbek</i> (Cacao-Alb) and <i>Acacia mangium</i> (Cacao-Aca) on total carbon stock (soil + biomass + litter) of the cocoa plantation. Carbon stock was assessed in the different soil, biomass and litter compartments at different distances from the AssT. Soil carbon stocks (0 to 30 cm and 30 to 60 cm depth) were predicted by previously calibrated NIRS model. Trees biomass was estimated using dendrometric indicators and allometric equation. Litter was picked up on 1m<sup>2</sup>. Data were analysed by a linear mixed model with blocks as random effect to test the effects of AssT and distance to AssT factors. Results indicate a significant decrease in cocoa biomass (<math>p &lt; 0.001</math>) related to AssT with a difference relating to the distance to AssT. Litter biomass showed no significant difference related to distance. However, the presence of AssT resulted in a significant increase in litter production (<math>p &lt; 0.001</math>). SOC showed a significant difference between treatments (<math>p &lt; 0.001</math>) with a decrease recorded under Cacao-Aca. Thus, on the 0-30 cm horizon, there was no significant difference related to distance, unlike on the 30-60 cm horizon. Depending on depth, SOC showed a</p>	<p>Silue, Brahim Masse, Dominique Kone, Armand</p>



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<p>significant difference (<math>p &lt; 0.001</math>) with a decreasing trend on the 0-30 and 30-60 cm horizons. Furthermore, total carbon stock showed significant difference (<math>P &lt; 0.001</math>) along to the distance range and with the presence of AsT. The SOC results could however be explained by Cacao-Alb litter quality which have a lower C/N ratio than other treatments. Thus, for a complete carbon balance at plot level, AsT biomass must be taken into account.</p>	
<p><b>Eco-physiological responses of adult cocoa plants to shade and water suppression</b></p> <p>Climate models predict decreasing precipitation and increasing air temperature among some cocoa growing regions in West Africa. Shading is known to improve microclimatic conditions around cocoa plants thus reducing radiation load on the leaf surfaces and improving cocoa physiology. Shade may help reduce the negative effects posed by drought as reports indicate reduced evapotranspiration and conservation of soil moisture under shade. However, there are few on-farm studies to provide information about the effects of shade on adult cocoa plants. Here, over a period of two years, we subjected twelve-year cocoa plants to three levels of water suppression (0, 1/3 and 2/3) and full sun or 40% uniform shade in a split plot design for two years to monitor stem water potential, chlorophyll fluorescence, gas exchange, litter fall and stem expansion. Volumetric soil moisture content ranged between 0.20 – 0.45 m<sup>3</sup>/m<sup>3</sup> along the soil profile with shade treatments having higher soil moisture contents. Water suppression reduced stem water potential to as low as -1.0 MPa especially under 2/3W plots in the full sun conditions. Pre-dawn chlorophyll fluorescence (Fv/Fm) was high in shade conditions with values around 0.8 but as low as 0.68 under 2/3 and full sun in the dry months. On the other hand, rates of photosynthesis in full sun conditions ranged between 6.75 to 9.04 <math>\mu\text{mol m}^{-2} \text{s}^{-1}</math> and between 5.3 to 7.7 <math>\mu\text{mol m}^{-2} \text{s}^{-1}</math> in the shade conditions depending on the suppression levels, however, gs values were comparatively low in full sun conditions. The results confirmed negative effects of low water availability on cocoa performance and shade as a possible solution to mitigate the effects.</p>	<p>Mensah, Eric Opoku Asare, Richard Vaast, Philippe Amoatey, Christiana Asitoakor, Bismark Owusu, Kwadwo Rabild, Anders</p>
<p><b>Expansion of fruit tree-based agroforestry in Northwest Vietnam by socio-economic and geographical context</b></p> <p>Driven by market opportunities, smallholder fruit tree cultivations, including in the form of integrated systems such as agroforestry, have expanded rapidly in the Northwest of Vietnam, a mountainous region dominated by ethnic minorities. According to the Government's statistic, the total area of fruit tree cultivations in the main provinces of the region in 2018 reached about 60,000 hectares or doubled compared to the area in the provinces in 2015. This study investigated the drivers of the system's expansion in three provinces of the region namely Yen Bai, Dien Bien, and Son La, using satellite imageries to identify spatial expansion areas of the systems in 2015 and 2019 associated with geographical condition such as land elevation and distance to main roads, and both structured and semi-structured interviews with farmers and local stakeholders to better understand diversity of the systems, motivation and main challenges that farmers from different socio-economic backgrounds had to face for adopting the systems, product marketing and policy supports. The results of the study are expected to draw increased attention from relevant decision makers in Vietnam on the better way to promote fruit tree-based systems as alternative farming system to monoculture annual crops in the upland region that are common yet economically and ecologically unsustainable.</p>	<p>Mulia, Rachmat Nguyen, Mai Phuong Minh, Tuan Dong Ngoc Tran, Thi Minh</p>

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<p><b>Tackling climate change and diversifying markets with a coffee agroforestry in the Atlantic Forest, Brazil</b></p> <p>The 'Atlantic Agroforestry' Project (PRETATERRA) were designed to impact positively 35 families and implement 100 hectares of agroforestry, impacting the landscape and starting an ambitious biodiversity corridor of wildlife in the Atlantic Rainforest region, one of the most endangered biodiversity hotspots in the world. Diversifying farmer's production and revenues guarantee food security, and reduces their dependence on the commodity market, while spinning-off rural development and entrepreneurship. Due to climate change, most monoculture plantations in Brazil are at risk. The agroforestry being implemented includes timber and NTFP for revenue diversification, as well as service trees for soil restoration and system's health maintenance. The pilot phase of the project is being conducted in Timburi, São Paulo State, where coffee plantations are traditionally cultivated for centuries. The conversion of traditional coffee monocultures to agroforestry involves a well-designed system that could address farmer's perceptions and culture, potential diversified markets, high-levels of carbon sequestration and mitigation of climate-change impacts. With the objective of providing a more homogeneous and diffuse shading while allowing coffee production and management, the coffee-design includes native fruit trees, timber and service species inserted in every 2 rows of coffee. Trees are arranged in lines every 12m, and every 1.5m within the line. There is one line of trees for every 3 lines of coffee, aiming to prioritize a partial and diffuse shading of the coffee. The species were selected based on the PRETATERRA method of functional-niche, occupying intelligently and architectonically the right stratum and moment in the succession. The E-W alignment maximize insolation within the rows enabling the production of cash-crops during the first years of the system and minimizing management. Forest-based solutions are the most important mechanism to tackle climate change. In Timburi we are involving several levels of stakeholders to guarantee market, capacity building, and food sovereignty.</p>	<p>Costa, Paula Noronha, Felipe Saka, Mariana Borges, Mateus Ziantonio, Victor Ziantoni, Valter</p>
<p><b>Typology of agroforestry systems based on cocoa in Côte d'Ivoire using aerospace technologies</b></p> <p>Côte d'Ivoire is the world's largest producer of cocoa beans, accounting for more than 42% of global production. However, for a long time, cocoa farming has been heavily dependent on the forest. Indeed, based on an unsustainable technical model of intensive cultivation involving the displacement of production areas, its expansion has greatly reduced forest availability in Côte d'Ivoire. Thus, forest, which covered more than 16 million hectares in 1960, will have less than 3 million hectares in 2021. To preserve a certain amount of forest cover, trees association with cocoa production is advocated and encouraged. Thus, agroforestry systems based on cocoa (SAFc) now appear to be a credible alternative for combining trees with cocoa. However, it's difficult to determine exhaustively cocoa farms composition and structure in Côte d'Ivoire, making it impossible to establish a good typology of SAFc and to determine the profitability. Indeed, trees number, their association and distribution in cocoa farms are not well defined at this stage, due to the lack of comprehensive studies on cocoa farms structural parameters and their impact on productivity. This deficit is caused, among other things, by the complexity of cocoa farms, their heterogeneity and their large size, which don't allow exhaustive field studies to be carried out. The main objective of this proposal is to improve the knowledge of SAFc characteristics in Côte d'Ivoire by using a drone equipped with multispectral sensor to determine the most sustainable and profitable systems for producers. This characterization will be based on a multi-criteria analysis by coupling data on cocoa farms structure and composition with economic and financial data for each SAFc. In light of the</p>	<p>Kouakou, Akoua Tamia Madeleine Kouakou, Kouassi Apollinaire Yedmel, Memel Charles Serge N'golo, Konaté Barima, Yao Sadaïou Sabas</p>

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<p>analyses, the most cost-effective SAFc will be promoted in order to ensure cocoa production sustainability in Côte d'Ivoire.</p>	
<p><b>Options-by-context for selecting shade trees in agroforestry systems: Case for coffee agroforestry in Indonesia</b></p> <p>Options-by-context is an approach used to identify a number of options based on the growing contexts in the particular areas and become commonly used to determine options of agroforestry designs based on the contexts that occurred. In a complex landscape like Indonesia, with diverse biophysical, social and economic entities, applying an options-by-context approach for selecting appropriate shade tree species for an agroforestry system becomes crucial. The current extension system usually uses a top-down approach for promoting shade trees for coffee agroforestry systems. This study demonstrated variation of selected shade tree species under coffee agroforestry system in Indonesia between different biophysical and socioeconomic contexts from the analysis of a total of 1,580 plot-level data from three distinct areas in Indonesia (Jambi (n=24), Lampung (n=1372) and South Sulawesi (n=208)). The analysis shows that farmers used different groups of shade tree species based on farmers' preferences and resources. Farmers in Lampung, known as the first rank of producer in Indonesia, tend to use low-economic beneficial NFTs species such as gliricidia and leucaena as shade trees. Farmers in alternative coffee-producing areas like Jambi use rubber and cinnamon as an alternative income from their coffee-based system. Farmers in a less-intensive coffee-producing area like Sulawesi use high-economic beneficial tree species such as surian (Toona sureni, timber), jackfruit (fruit) and cloves (spice) as intercrops. Main contexts that determine options of shade trees for the coffee agroforestry system in Indonesia can be divided into these three categories 1) benefits to coffee's biophysical suitability; 2) farmers' livelihood resilience; and 3) social consideration in local knowledge systems. For changing the top-down paradigm of promoting shade tree species, extension agents need to understand and consider those three main contexts when promoting shade tree species for agroforestry systems to farmers.</p>	<p>Permadi, Dikdik Subekti, Rahayu Martini, Endri</p>
<p><b>Greenhouse gas reduction for climate change mitigation: Biodiversity and carbon sequestration in cocoa agroforests (<i>Theobroma cacao</i> L.) in Togo (West Africa)</b></p> <p>Agroforests carbon sequestration remained greenhouse gas (GHG) reduction emissions effects approach facing climatic changes. Present study objectives were to analyze biodiversity in coffee agroforests and to evaluate carbon sequestration potential in these agroforests in Togo. Inventories of agroforestry trees associated to coffee trees have been achieved in 166 plots installed in 72 localities distributed on the eight coffee producers' districts with each four coins parcels for measuring coffee trees. Data treatments permitted to value carbon stock in aboveground biomass. Results showed that coffee agroforests were characterized by the presence of forest trees with average size (height <math>14.76 \pm 3.62</math> m and diameter <math>38.94 \pm 19.85</math> cm), a coffee trees density of 3 733 rods/ha and associated trees density were <math>460 \pm 164</math> rods/ha with a trees basal area of <math>0.10 \pm 0.06</math> m<sup>2</sup>/ha. Coffee agroforests were rich of 55 agroforestry trees species distributed between 43 genus and 23 families, who were in 78 % a native species dominated by Fabaceae (16 %), Moraceae (13 %), Meliaceae (7 %) and Ceasalpiniaceae (7%) with 25.45 % dominance of legumes. The presence of two vulnerable species (<i>Terminalia ivoriensis</i>, 0.07 % and <i>Triplochiton scleroxylon</i>, 0.22%) and a specie seriously threatened (<i>Garcinia afzelii</i>, 0.22%) was important to be preserved. Shannon index (4.59 bits) and Pielou index of equitability (0.79) showed that these agroforests were diversified. Total biomass was <math>136.87 \pm 84</math> t/ha in average with carbon sequestration capacity of <math>98.56 \pm 36.11</math> t C/ha, an equivalent CO<sub>2</sub> of <math>362.50 \pm 179</math> t CO<sub>2</sub>/ha (95 % of confidence interval of 76.71 t/ha and 1.34 % of mistake in</p>	<p>Adjonou, Kossi Adden, Ayi Koffi</p>

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<p>percentage). Coffee agroforests in Togo constituted at least a carbon well of 2 354.35 Gt with an equivalent CO<sub>2</sub> of 8 640.46 Gt. Preservation of this perennial crops and its potential will be a pledge of GHG effect reduction and therefore the mitigation of global changes effects.</p>	
<p><b>Changements climatiques et résilience des agriculteurs dans le bassin agricole du Noun: Une approche climato-intelligente autour de l'agroforesterie</b></p> <p>Les changements climatiques constituent l'un des défis majeurs de notre temps du fait de leurs impacts sur l'environnement et sur la sécurité alimentaire. Au Cameroun, près de 60% de la population pratique l'agriculture comme principale activité économique. Malheureusement, d'années en années, la paysannerie camerounaise fait face à une baisse considérable de la production agricole du fait des perturbations pluviométriques. En effet, devient-il urgent de développer les stratégies durables d'adaptation et d'atténuation des effets négatifs du changement climatique sur l'environnement et sur la production agricole. L'une des stratégies que nous avons mises sur pieds dans le bassin agricole du Noun à l'ouest du Cameroun, est une approche climato-intelligente des pratiques agricoles sous forme de projet pilote sur l'utilisation conjointe des cultures vivrières et de l'agroforesterie. Dans notre projet, nous avons planté en 2021 des centaines d'arbres fruitiers économiquement rentables, sur cinq hectares de terres agricoles, auxquels nous avons associés cinq cents tiges de manioc. Notre première récolte des fruits est attendue en juillet 2023. En tant que fixateurs d'azote, ces arbres fruitiers vont enrichir le sol en capturant dans l'atmosphère des éléments essentiels pour les plantes. Cela réduira ainsi les besoins en engrais azotés chimiques, qui participent généralement au réchauffement climatique et à la pollution de l'environnement. Aussi, l'agroforesterie constitue un système de production adapté aux changements climatiques et aux besoins des populations. Car les arbres fruitiers vont non seulement protéger les autres cultures du vent, des sécheresses, du grand froid mais aussi rapporter des revenus substantiels aux populations à travers la commercialisation des fruits qui connaissent une embellie sur le marché national et international. A termes, si le projet produit les résultats escomptés, nous comptons créer un groupe d'initiative commune avec d'autres paysans afin de promouvoir et de vulgariser cette approche climato-intelligente pour un plus grand impact dans la région.</p>	<p>Mefire Mfondi, Mariatou</p>
<p><b>The Voatsiperifery of Madagascar, from abusive exploitation of resources to sustainable agroforestry</b></p> <p>The wild pepper or voatsiperifery —an endemic species to Madagascar—belongs to the same family as Pepper nigrum (black pepper). It is mainly found in the rainforests of the island and due to the pressure on this product which has led to strong degradation of natural resources, its exploitation is now prohibited. However, it has been a subject of particular attention and has had an increasing demand on the international market. Since 2010, 30 to 50T per year is exported with a selling price of up to 500 euros per kilogram. It is therefore important to understand the different systems of exploitation of this resource to sustain the economic activities in this sector. In an area located in the South East of Madagascar, in Fort Dauphin, the exploitation of this rare resource was studied in 2021. Investigations were conducted in three large collection areas producing 5 to 10T of products, managed by three families of smallholders. In the other collection areas, either the stake is cut down or the vine are pulled up in 99% of the cases during the harvesting process. The agroforestry systems that support wild pepper are preserved through environmentally friendly practices. While the voatsiperifery agroforestry was usually composed of forest species or precious woods, they can now grow on cash crop plants such as coffee. This evolution has encouraged domestication trials of this product, thus reducing the environmental pressure in</p>	<p>Rabodomanantsoa, Aina Fehizoro Randrianantsoa Chateaneuf, Mima Rafitoharson, Elodie Richard, Matthieu Omnes, Marc Andriamihajaso, Toky Fanantenana</p>

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<p>the original agroforestry systems, which can lead to sustainable exploitation of this forbidden fruit.</p>	
<p><b>Potential impact of different seed sources on quality seed production of <i>Toona ciliata</i>: Species coming into prominence in Agroforestry</b></p> <p><i>Toona ciliata</i> is one of the Indian native, fast-growing, multi-purpose, high class timber species across the globe. In the north-western Himalayan region, the species is commonly planted in social forestry and farmlands as circa situm conservation as well as cultivated along with agricultural crops. The existing natural variation concerning to climatic condition, elevation, phenology, and habitat helps breeders to select superior trees followed by evaluating progenies to know the genetic worth/ breeding values. Better growth could be achieved through selecting superior planting material (seed). Therefore, a research rationale was formulated with the emphasis on seed source variation to screen potential germplasm for ameliorating timber productivity. The fruits from phenotypically superior trees were collected from ten different provenances belonging to the western Himalayas in contemplation to assess variation in seed characteristics. Analysis of variance revealed the presence of highly significant variation among the selected seed sources for all the fruit and seed traits except moisture content in the seed. High estimates of genotypic coefficients of variation (GCV) were obtained for fruit width and 1000 seed weight, and moderate for the rest of the characters. Similarly, the phenotypic coefficients of variation (PCV) were high for fruit width, moisture percentage, 100 fruit weight, and 1000 seed weight; and moderate for rest of the characters. High estimates of heritability (<math>h^2</math>) and genetic advance were obtained for all the traits except moisture content. Seed source TC 29 was found superior for 100 fruit weight, number of seeds per fruit, and moisture content; TC 50 for fruit width, seed width and 1000 seed weight. These results further elucidate that these variations have enormous potential to ameliorate the productivity and adaptation capability of <i>T. ciliata</i>. Hence, the selection of diverse seed sources could play a significant role in productivity enhancement.</p>	<p>Neha, Neha Kant, Rama Bhandari, Maneesh Singh Kurmanchali, Madhubala</p>
<p><b>Assessing tree structure and biomass of windbreaks by terrestrial LiDAR</b></p> <p>A common practice is the deliberate utilisation of trees to form windbreaks in agroforestry systems. These vegetative structures provide a reduction in wind speed, reduce evapotranspiration of the sheltered crops and can positively influence crop production. The nature and spatial arrangement of linear windbreaks imposes particular growing conditions on the trees, resulting in stem, branch and crown structures that are different to those found in forests, or more open landscape conditions. Together with the knowledge gap about structural features of such trees, the assessment of biomass and its spatial and functional distribution is relevant for better understanding carbon sequestration within such systems. We assessed a windbreak situated within a commercial vineyard in the Paarl wine district of the Cape Winelands (Western Cape, South Africa; 33°39'27.69"S, 18°55'19.53"E, 194 m a.s.l.) by means of terrestrial LiDAR in two instances: in the beginning (leaf-off) and towards the end (leaf-on) of the growing season of 2020-2021. A continuous single-row (150 m) of Simon poplar (<i>Populus simonii</i> Carrière) was targeted for the presented study. The windbreak is located in-between citrus and wine plantations, and has a within row tree spacing of below 1 m. The local climate of the region is regarded as Mediterranean, with wet winters and dry summers, and an average annual rainfall sum of about 770 mm. Seeking a better description and structural understanding of windbreak, the acquired 3D-data were processed into individual tree point clouds and tree structural measures were derived with Quantitative Structure Models (QSMs). Preliminary results revealed substantial differences between tree dimensions in</p>	<p>Bohn Reckziegel, Rafael Sheppard, Jonathan P. Seifert, Thomas Morhart, Christopher Kahle, Hans-Peter</p>



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<p>the windbreak sessions, which is directly associated to the protective functions provided. While porosity is not directly assessed, biomass estimates gave insights on the windbreak density.</p>	
<p><b>N-fertilizer application does not increase canopy leaf area in 20-year-old cocoa plantations</b></p> <p>In West Africa, cocoa is mostly produced on smallholder farms which is mainly low-input system characterized by inadequate soil fertility management practices and low productivity. Increase fertilizer application on nutrient-depleted soils is expected to boost photosynthesis, so that pod production increases as photo-assimilates become more available. Foliar growth is an important ecological mechanism that contributes to increase in photosynthesis. In particular, nitrogen (N) supply is thought to stimulate cocoa leaf flushing and increase leaf area. Yet, the effect of N-fertilizer application on cocoa leaves is poorly understood and current fertilizer recommendations for cocoa do not all include N in their formulation. In an on-farm experiment, early effects of N-fertilizer application on leaf growth were evaluated on 15-20 year old cocoa trees traditionally grown under light shade conditions in Ondo state, Nigeria. Treatments were control (no fertilizer), PK (50 kg P/ha and 50 kg K/ha), N50PK (50kg N/ha, 50 kg P/ha, and 50 kg K/ha), and N100PK (100 kg N/ha, 50 kg P/ha, and 50 kg K/ha). Leaf flushing was monitored monthly, and leaf biomass dynamics assessed through canopy gap analysis, specific leaf area, and litterfall collection. We found no significant increase in leaf biomass of the canopy when fertilizer was applied. Rather, new leaf flushes were 15% more abundant (<math>P &lt; 0.05</math>) on trees in control plots. Nevertheless, cocoa trees that received fertilizer temporarily shed up to 23% (<math>P &lt; 0.05</math>) less leaves than in unfertilized trees when a mild dry-spell occurred. This leaf retention effect increased with N rates, but did not last more than 6 weeks to trigger any significant difference in annual cocoa leaf litterfall (<math>P &gt; 0.05</math>). We concluded that under the specified experimental conditions, fertilizers - especially N - did not stimulate cocoa leaf growth, but slightly reduced canopy leaf loss induced by water deficit.</p>	<p>Hougni, Deo-Gratias Hauser, Stefan Suleiman, Fatimoh Ogunlade, Moses</p>
<p><b>Effect of management options, some ecological factors and soil fertility on cocoa yields in cocoa agroecosystems of Southern Cameroon</b></p> <p>The Center Region currently produces over 40 % of cocoa in Cameroon. Serious yield gaps exist among farmers that are generally attributed to farm management, and decline of soil fertility. Hence, this study was conducted to access the relationship between certain yield factors and average cocoa yield of selected cocoa agroecosystems in the center region alongside a yield gradient from June to December 2020. Investigation of 100 farmers using semi-structured questionnaires to capture farm management practices was done. Thirty (30) cocoa agroecosystems were assessed for specific bio - physical characterization ; soils were sampled at a depth of 0 – 30 cm and analysed, cocoa leaf diagnosis was also done. Average cocoa yield of 630.1 kg/ha was obtained. Pearson's correlation coefficient calculated shows that ; estimated cocoa yields increase significantly with cocoa agroecosystem surface area (<math>r = 0.7087</math> ; <math>p = 0.0001</math>) and the variety of cocoa grown (<math>r = 0.6769</math> ; <math>p = 0.0003</math>) but decreases significantly with an increased in associated trees densities (<math>r = -0.7148</math> ; <math>p = &lt; 0.0001</math>) and plant diversity (<math>r = -0.7029</math> ; <math>p = 0.0001</math>). Finally through regression analysis and stepwise variables selection (direction = backward/forward ; criterion = „AIC') ; frequency of spraying insecticide against capsids, soil K, Mg, soil structural parameter sand, and associate's tree species densities had a significant impact on cocoa yield. These implies that, poor management of soil K and Mg content of the studied soils and an increase in associate's tree density are likely to be responsible for yield decline. Hence, particular attentions need to be made on these parameters as far as cocoa</p>	<p>Milie Lionelle, Tsouga Manga René, Menoh A Ngom Adalbert, Onana William Armand, Mala Marie, Mbolo Didier, Begoude Cargele, Masso</p>



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cultivation in this area is concerned. Also, farmers need to adopt and respect better farming management practices.	
<p><b>Typology of cocoa-based agroforestry systems in Madagascar: a tool for a sustainable management</b></p> <p>Cocoa agroforests are a farming system well known for its importance on the local population livelihoods. In Madagascar, specifically in the northern region (main cocoa producing areas), it contributes importantly to the livelihoods of an over 80% of local population. However, which systems should enhance these benefits while respecting the environment? In order to understand the cocoa agroforests in that region, 150 producers were investigated individually this year 2021. Field observations was conducted in each plot surveyed and a sample of 30 plots of 60m x 40m among them was inventoried. The characteristics observed concerned the age of the plantation, previous crop, yield, density, types of associated species, frequented elevation, forms of agroforestry systems practiced, as well as the orchards management. The results showed that the cocoa agroforests in this region, are generally characterized by: age-old cocoa farms with an average of 20-40 years (71%), previous crop dominated by coffee (66%), an average of yield 710kg/ha/year, a high plantation density (550 feet/ha of cocoa trees and 80 feet/ha of associated trees), cultivated on a wide variation of altitude levels (10 to 400m), a dominance of agroforestry system (97%) and a very low proportion of crop maintenance and fertilizer use (5%). 31 associated tree species grouped into 15 families were encountered. They were fruit and forest species who uses for shade, food, timber and commercial. Fabaceae, Moraceae, Anacardiaceae and Annonaceae appears dominant families. In terms of richness and diversity, the Shannon index obtained was 2.13 and 0.663 for the Pielou equitability index. Indeed, cocoa-based agroforestry systems in this region are diversified with their associated species allowing producers to increase their income and maintaining their food-needs and wellbeing during the poor production season of cacao. Additional statistical analysis will be carried out to define the typology of this agroforestry systems.</p>	<p>Marizia Roberta, Rasoanandrasana Nandrianina, Ramifehiarivo Eric, Delaitre Herintsitohaina, Razakamanarivo Hery Lisy Tiana, Ranarijaona</p>
<p>M. Which Agroforestry for Integrating Livestock to Trees and Crops?</p>	
<p><b>Shrub fodder banks, an agroforestry technology for agroecological intensification of livestock feeding in West Africa</b></p> <p>West African livestock keepers need forage sources to feed animals without degrading the local fragile ecosystems. To feed animals, they usually combine natural resources (including pruning fodder trees/shrubs during the dry season), crops residues and other more or less locally available alternative feed resources. This study aimed at producing agronomic, economic, social and environmental references to evaluate six existing high-density shrub fodder banks (SFB) established in 2016-2017 (20,000 plants/ha) in three different zones of Burkina Faso for low-input intensive fodder production. From 2017 to 2021, we monitored biomass yield in each SFB plots, over two tri-monthly harvests each year. Fodder harvested were evaluated and preserved dry for animal supplementation especially in dry season when pastures are scarce. At each harvest period, samples of fodder species were collected and analysed for chemical composition. In 2021 an inventory of plants in the six SFB was done and we conducted an economic and social assessment of SFB management with experimental farmers. The soil aggregate carbon under the SFB were evaluated. Then a feeding trial involving 12 young zebus' cattle was conducted for 21 days including 14 days of adaptation and</p>	<p>Sib, Ollo</p>

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<p>7 days of data collection. The feeding treatment were: T1: 75% Andropogon gayanus 25% Leucaena leucocephala, T2: 75% Andropogon gayanus 25% Gliricidia sepium, T3: 100% Andropogon gayanus. Liveweight of animals, feed offered, refusals and total feces were daily collected. The six famers had well integrated the use of SFB into their livestock feeding habits with low management cost and no external inputs, albeit with a moderate increased workload. Biomass yield per SFB (t DM/ha/yr) increased from 2017 to 2019 (2017 =11.1 t; 2018 =12.0 t; 2019 =15.2 t) before declining to 11.0 t in 2020 and increasing slightly again in 2021 (12.5 t) with improved agronomic practices. Feed trials showed that T1 and T2 had higher daily mass gain than T3 fed with 100% Andropogon. Results demonstrate technical and socio-economic viability and the potential of this low input agroforestry technology for contributing in agroecological way to overcome current feed shortages limiting livestock farming. However, to maintain high production over the long term, appropriate management of the SFB plots should be applied.</p>	
<p><b>Leading the transition to a diversified carbon sink protein-based agroforestry</b> Forage-based livestock models are very diverse and divergent. Aiming to create an agroforestry livestock-model meeting scalability, sustainability, and financial viability, the PASTO VIVO project proposes a diversified agroforestry design to transform the cattle production chain on large scale using high-value trees, for NTFP, fuel, and timber. During the first 3-4 years, grains are produced between the tree cluster (30m) while the tree clusters (8 m wide) grow together with sunflower and Cajanus cajan. The heifers enter the land in the fourth year onwards, after the last harvest of grains and when the pasture enriched with Tithonia diversifolia and Cajanus cajan is planted. The clusters of trees are composed of two outer-lines of a dwarf variety of cashew (for nuts) intercropped with palms for oil (Acrocromia aculeata). The centerline (spaced 4m from each other line) is composed of Dypteryx alata (for nuts) and Myracrodruon urundueva (timber tree). The outer-lines provide the initial shade needed for the establishment of the centerline's forest species. The palm has high canopy permeability, allowing high insolation. Cashew tree is pruned annually, allowing sufficient light in the system, also generating biomass. The timber tree (M. urundueva) reaches the upper-crown layer of the system and the D. alata occupies the upper layer. This arrangement allows animals to access pasture in the entire system, also providing shade, shelter, and thermal comfort. The spacing also ensures optimal mechanization. The logic of the system obeys the metrics of modularity, replicability, and elasticity, offering a landscape-based solution for the entire region. The system is a carbon sink cattle-based agroforestry. Carbon sequestration estimations show a potential of 15 ton of CO<sub>2</sub> (eq)/hectare–1.year. Considering carbon as a key factor for success and calibrating the system for facing climate change challenges are key factors to scale-up nature-based solutions for livestock production in Brazil.</p>	<p>Ziantoni, Valter Domiciano, Leandro Lemos, Everton Borges, Mateus Saka, Mariana Noronha, Felipe Costa, Paula</p>
<p><b>Effect of polyherbal supplementation in peripartum period on milking performance of crossbred cows</b> An experiment was conducted to evaluate the effect of supplementation of polyherbal mixture containing Asparagus racemosus, Leptadina reticulata, Tinospora cordifolia, Withania somnifera and Lepidium sativum (10:15:10:15:50) on the milking performance the of crossbred cows maintained at the dairy farm of Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) India. In the experiment total 12 crossbred cows in their 3rd to 5th lactation were selected on the basis of their previous lactation milk yield and were divided into 2 groups of 6 animals in each group. Animals in the treatment group were supplemented with the polyherbal mixture @ 100 gm/day for a period of 105 days i.e. 15 days pre</p>	<p>Gautam, Krishan Lal Bishist, Rohit Thakur, Chaman Lal Sharma, Archana Kishore, Kamal</p>

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<p>calving to 90 days post calving. Milk yield of the individual animal was measured daily and the milk samples were collected on fortnightly interval to estimate the milk fat, SNF, total solids and milk protein content. Study revealed that the feeding of the polyherbal supplement to cross bred cows resulted higher average daily milk yield in treatment group (8.70 kg day<sup>-1</sup>) as compared to the cows (7.38 kg day<sup>-1</sup>) which were not offered this mixture. Milk quality parameters viz. milk fat, solid not fat, total solid and protein (%) were also significantly higher in treatment group (4.21, 8.67, 12.83 and 3.44) as compared to control group (3.52, 8.34, 11.86 and 3.34). While studying the economic feasibility of the trial it was observed that the net return was higher (157.08 Rs day<sup>-1</sup> Cow<sup>-1</sup>) in treatment group as compared to control (112.97 Rs day<sup>-1</sup> Cow<sup>-1</sup>) with a B:C ratio of 1.6. The study concluded that feeding of polyherbal mixture to the crossbred cows resulted in 9.3 per cent higher milk yield, better milk composition and achieving early peak lactation with higher persistency.</p>	
<p><b>Forest Tree Leaves for Parasitic Control in Goats of Reasi district of India</b>  Background : Parasitic infection of the digestive tract is one of the main constraint to goat production both in temperate and tropical countries. The performance and productivity of goat is adversely affected by helminthic infections. Infected goat either don't gain expected weight or lose weight, become lethargic, and may have severe diarrhea. The control of helminth infections has always been a challenge. There is a need of more sustainable and drug free treatment that can help in control of parasitic infections in goats. Locally available tree leaves like Neem (<i>Azadirachta indica</i>) Guava (<i>Psidium guajava</i>), Mango (<i>Mangifera indica</i>), Jamun (<i>Syzygium Cumini</i>), Amla (<i>Emblica officinalis</i>), found in hilly areas of Jammu and Kashmir can be used in complete feed blocks to meet the protein deficiency as well as control the parasitic load of the sheep.  20.00±0.44, 10.58±0.54, 11.02±0.11, 25.56±0.48, 10.62±0.57 is the CP content of these leaves respectively. Objectives : The study was carried out to assess the effect of Complete feed blocks and condensed tannins (CT) supplementation through leaf meal mixture (LMM) on feed intake and faecal egg counts in <i>Haemonchus contortus</i> infected goat. Methodology : 60 goat were randomly divided into three groups (C, T1 and T2) of 20 animals in each group in a completely randomized block design for a period of 4 months. T1 group was supplemented with complete feed blocks without any leaf meal mixture whereas T2 group was supplemented with leaf meal mixture @ 1.5%. Body weights were recorded at 0th day and then 15th day's interval for a period of 90 days to assess feed intake and body weight changes. The faecal samples were collected at 0th, 7th, 15th day and thereafter at 15 days intervals for a period of 4 months for the assessment of <i>H. contortus</i> loads. Results : The study showed that feed intake and weight gain was almost similar in both the treatment groups T1 and T2 but were comparatively better than the controlled group with normal feeding. The mean faecal egg counts was significantly (<math>P &lt; 0.001</math>) higher in T1 group as compared to T2 group. It may be concluded that dietary supplementation of CT (1.5 %) through LMM improved the overall growth and production and thus can help poor hilly farmers in making sheep farming an economically viable enterprise. Notes- Supplementation of CT through leaf meal mixture could be used as an alternative sustainable method to control <i>H. contortus</i> infection. Use of local tree leaves for long term can prove to be economically and healthy method to control parasitic infection in goats.</p>	<p>Azad, Mandeep Singh  Kour, Kwarddeep  Birwal, Preeti</p>

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<p><b>Soil properties of silvopastoral systems in the Peruvian Amazon</b></p> <p>Agriculture and livestock are motivated by the need to satisfy food and health needs. With that purpose, large areas of forests have been deforested to create large areas of farms or pastures for raising livestock. Silvopastoral systems (SPS) have been deemed as an alternative approach for land management with potential to improve degraded grasslands and the overall systems 'sustainability in the Peruvian Amazon. The objective of this research was to characterize the soil properties to evaluate soil degradation of eleven different SPS in selected farmer's fields in the districts of Molinopampa and Huayabamba of the Amazonas Region and Moyobamba in San Martin region in Peru. At each SPS, samples were collected at two sites, under the canopy and in the open field and at two depths. The evaluation of soil properties included bulk density (BD), soil moisture, total porosity, mechanical resistance, texture, organic matter, N, P, K, and cation exchange capacity. In Molinopampa, the SPS with Cypress (<i>Cupressus sempervirens</i> L.), Pine (<i>Pinus patula</i>) and Pona (<i>Ceroxylon peruvianum</i>) presented a lower degree of soil compaction during the rainy season, while the Alder (<i>Alnus acuminata</i>) system showed a slightly higher value. The soil fertility for the Alder and Cypress systems was medium while low fertility for the Pine and Pona systems. In Huayabamba, the BD was higher in the Eucalyptus (<i>Eucalyptus torrelliana</i>) and lower for the Pona and Guaba (<i>Inga edulis</i>) systems in the dry season and the soil fertility was medium. In Moyobamba, the BD ranged between 1.16 to 1.34 gr/cm<sup>3</sup> for Guaba, Eucalyptus and Tornillo (<i>Cedrelinga cateniformis</i>) systems being higher in Eucalyptus system. The most compacted SPS was the Eucalyptus system with the lower fertility.</p>	<p>Alegre, Julio Sanchez, Yenny Pizarro, Dante Gomez, Carlos</p>
<p><b>Use of <i>Tithonia diversifolia</i> (Hemsl.) A. Gray as a production improvement and GHG mitigation strategy under silvopastoral systems in the Amazon</b></p> <p><i>Tithonia diversifolia</i> can improve the ruminal fermentation and increase the amount of nutrients in diets in cattle systems under tropical conditions, but limited studies have evaluated the effect of this species under grazing conditions. The objective of this study was to determine the effect of silvopastoral systems (SPS) with <i>T. diversifolia</i> on GHG emissions and bovine milk production to identify both mitigation and productivity improvement strategies in small and medium-sized farmers in the Amazonian. Two cattle systems were evaluated in three sites in Caquetá (Colombia): a traditional system (TS) based on <i>Urochloa humidicola</i> and a SPS based on <i>U. humidicola</i> + <i>T. diversifolia</i> with scattered trees of <i>Gmelina arborea</i>, <i>Erythrina poeppigiana</i> and <i>Cariniana pyriformis</i>. Enteric fermentation emissions were measured using the Poly tunnel technique and manure emissions (CH<sub>4</sub> and N<sub>2</sub>O) were determined using the closed chamber technique. <i>T. diversifolia</i> increased milk production (4.32 vs. 4.73 kg LCGP/animal/day, respectively) (<math>p = 0.0052</math>) and CH<sub>4</sub> emissions decreased with its supply (<math>p &lt; 0.05</math>). Emissions per animal/day, per kg DM consumed and Ym were: 217.1 (<math>\pm 33.8</math>) vs. 207.4 (<math>\pm 35.15</math>) g CH<sub>4</sub>/animal/day; 27.84 (<math>\pm 1.13</math>) vs. 25.42 (<math>\pm 1.06</math>) g CH<sub>4</sub>/kg DM consumed; 8.20 (<math>\pm 0.59</math>) vs. 7.86 (<math>\pm 0.38</math>) %, for TS and SPS, respectively; emissions per unit of product were also decreased with <i>T. diversifolia</i>. In manure, SPS emitted 0.89 and 0.13% of the N deposited in urine and feces, while TS emitted 1.68 and 0.17%, respectively (<math>p &lt; 0.05</math>), and CH<sub>4</sub> emissions from feces were 1.08 and 0.83 g CH<sub>4</sub>/kg DM of feces for TS and SPS (<math>p &lt; 0.05</math>). SPS with <i>T. diversifolia</i> can emit lower amounts of CH<sub>4</sub> and N<sub>2</sub>O, which could be alternatives to mitigate these gases in bovine systems in the Colombian Amazon, increasing milk production; identifying mitigation alternatives is relevant because currently Colombia made a commitment at COP 26 to reduce its emissions by 51% by 2030.</p>	<p>Rivera, Julian Esteban Villegas, Gonzalo Chará, Julian Murgueitio, Enrique Durango, Sandra Romero, Miguel Verchot, Louis</p>



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<p><b>Silvopastoral systems contribute to recover biodiversity in deforested areas of the Amazon foothills in Colombia</b></p> <p>The department of Caquetá in the Amazon foothills of Colombia is one of the most dynamic in terms of cattle production in the country. This activity occurs at the expense of tropical forest that have been replaced by pasture monoculture with negative consequences for the biodiversity and the provision of environmental services. Silvopastoral systems (SPS) have been promoted in the region as an alternative to recover part of the tree cover, biodiversity and productivity of cattle farms. To analyze the impact of SPS on plant and bird diversity, 22 plots with three silvopastoral arrangements (tree alleys: TA, scattered trees in pastures: STP, intensive silvopastoral systems: iSPS) and pasture monocultures (PM) were sampled using 20x50 quadrats for vegetation and 50m radius fixed points for birds. A total of 556 individuals of 26 families and 60 plant species were found. TA had significantly higher abundance (324 individuals) and richness (42 species) of vegetation. For bird fauna 2209 individuals belonging to 21 orders, 43 families and 182 species were present. As for plants, the highest abundance and richness was found in TA (891 individuals, 143 species) followed by STP with 523 individuals and 101 species, and were significantly higher than PM with 82 individuals and 28 species observed. Bird diversity, bird abundance and insectivorous and frugivorous bird richness had a high positive correlation with plant richness and abundance. Vegetation structure, measured as canopy cover, total volume of vegetation, and leaf density index had an important influence on frugivorous and total bird richness. In general, the three silvopastoral arrangements promoted contributed to increase significantly plant and bird diversity when compared with traditional PM. Plant diversity and structure complexity is key to improve diversity of birds, frugivorous and insectivorous species and therefore should be considered when selecting plant species to be introduced in the cattle systems.</p>	<p>Giraldo, Lina Castaño-Quintana, Karen Chara, Julian Velasquez, Alexander Murgueitio, Enrique</p>
<p><b>Risk analysis for the installation of sylvo-pastoral systems in the Romanian Plain</b></p> <p>Sylvopastoral system are a pioneering field in the transition from a family animal husbandry developed in microfarms to an intensive animal husbandry developed in medium-sized farms and facing the vicissitudes of a constantly changing climate, especially in a steppe-type continental plain such as the Romanian Plain. Crop installation has been dimensionally framed by reference to installation and maintenance costs and repeatability of the event of damage. Risk factors were classified into 3 main categories: 1 - topoclimatic factors and their destructive events; 2 - work planning and human activity; 3 - the unpredictable behavior of herds of animals. The method of measuring the intensity of the action of these factors was based on the rates of losses recorded in the installation and maintenance of sylvo-pastoral systems and the percentages of technical and financial efforts necessary to rehabilitate them to the size originally designed. The risk analysis was based on calculations of the determinants established by measurements and observations. In conclusion, out of all the 3 main groups of determining factors, the ones with the highest weight were established and also corresponding to them the measures to neutralize or diminish the negative effects produced. We proposed this analysis as a model for owners and entrepreneurs who want to design sylvopastoral systems with their known benefits on the development, protection and health of farm animals.</p>	<p>Popovici, Laurentiu Mihaila, Elena Constandache, Cristinel</p>
<p><b>Forage species production and nutritive value in Arkansas pine silvopastures</b></p> <p>This project evaluated the production and nutritive value of 8 forage species established in a 25-year-old loblolly pine (<i>Pinus taeda</i>) plantation to increase grazeable land on small beef farms. Experiment 1 evaluated 4 annual species, crimson clover (CC; <i>Trifolium incarnatum</i>), arrowleaf clover (ALC; <i>Trifolium vesiculosum</i>), annual ryegrass (AR; <i>Lolium multiflorum</i>), and tetraploid annual</p>	<p>Nieman, Christine Philipp, Dirk</p>

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<p>ryegrass (TAR). Experiment 2 evaluated 4 perennial species, orchardgrass (OG; <i>Dactylis glomerata</i>), tall fescue (TF; <i>Festuca arundinacea</i>), alfalfa (ALF; <i>Medicago sativa</i>), and white clover (WC; <i>Trifolium repens</i>). In Fall 2019, forages were established into prepared seedbeds, 9.1 by 2.4 m each, with three replicates. Forages in Experiment 1 were harvested on 2 April, 21 May, and 10 July, while Experiment 2 had an additional harvest date on 1 October. Total yield was analyzed as a complete randomized block design for species effects. Crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) were analyzed similarly but included harvest date as a repeated measure. Total yield averaged 4.4, 4.2, 3.5, and 2.7 Mg ha<sup>-1</sup>, for AR, TAR, ALC, and CC, with AR and TAR greater (<math>P&lt;0.01</math>) than CC, but ALC was intermediate and not different from other species. For Experiment 2, total yield averaged 5.5, 4.5, 4.0, and 3.3 kg ha<sup>-1</sup>, for TF, OG, WC, and ALF. Greatest yields (<math>P&lt;0.001</math>) were observed for TF, with OG and WC intermediate, and all yields were greater than ALF. In both experiments, species by harvest date interactions (<math>P&lt;0.01</math>) were observed for CP, NDF, and ADF. Generally, CP was greater in April and May with lowest values for CP and greatest values for NDF and ADF observed in July for all species. All nutritive value parameters were similar among species during spring, but legumes had greater CP values in July compared to the other forages.</p>	
<p><b>Systematic integration of crops, shrubs, trees and livestock in the West African Sahel for resilient livelihoods (SustainSahel)</b></p> <p>In the West African Sahel land degradation and soil erosion severely affect more than 80% of range- and farmlands. In addition to social, economic, political and cultural drivers—such as unsecure land/tree tenure—land is degraded by ecological, agronomic, and biological factors such as heavy soil weathering, short rainy seasons, low and erratic rainfall, low biomass productivity and overgrazing. SustainSAHEL is a recently initiated (September 2020) Horizon 2020 funded project conducting biophysical and socio-economic research that can be used by the people of the West African Sahel to build capacity and develop networks to help them create sustainable dryland farming systems and viable (rural) livelihoods. The overall objective is to enhance the resilience and intensification potential of smallholder agricultural farming systems to climate change through scalable innovations on crop-shrub/tree-livestock (CSL) integration. Systems approaches are a core concept of SustainSAHEL and reflect the linkage of biophysical, socio-economic, cultural and political realities. SustainSahel will assess adoption and scaling potential of improved CSL integration, while simultaneously optimizing proven technologies, improving herder-farmer cooperation, tackling socio-economic constraints for adoption and contributing to local economic revival. Investigations on CSL, are being conducted through 15 on-station and 80 on-farm experiments and demonstration plots across Senegal, Mali and Burkina Faso. We are investigating drought resistant shrub teams that are in synchrony with livestock requirements, and reduced tillage options that enhances the soil water capture and holding capacity. At the regional level, landscape modelling scenarios are analyzing the promoted systems' resilience to climate change in West Africa. The first-year results from the field and on-farm experiments are currently being collected/analyzed and some will be presented at this conference.</p>	<p>Cicek, Harun</p>
<p><b>Forage mixtures production in olive orchards under rainfed conditions: case study in North Africa</b></p> <p>Olive trees are largely cultivated in North Africa region, mainly under rainfed conditions. Mechanic tillage is a common practice used for managing vegetation between the rows of olive trees causing soil degradation water loss. The agriculture production system in this region is mainly based on crop-livestock integration requiring high amount of biomass production for animal feeding. In</p>	<p>Cheikh M'hamed, Hatem Ouabbou, Hassan Cicek, Harun</p>



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the framework of ConServeTerra project, funded by EU-PRIMA initiative, research studies were conducted in Tunisia and Morocco in order to investigate the feasibility of the biomass production including forage mixtures under olive orchards by adopting conservation agriculture. Trials were implemented in Meknes and Siliana regions, in Morocco and Tunisia respectively, during the growing season 2020-2021. The treatments investigated were: i) T0: Olive trees without crops between the rows with tillage, ii) T1: Olive trees with spontaneous vegetation between the rows without tillage, iii) T2: Olive trees with forage mixtures between the rows under conservation agriculture. Results showed that total dry matter of forage mixtures produced between the rows of olive trees were 5.22 t ha<sup>-1</sup> and 4.5 t ha<sup>-1</sup>, respectively for forage mixtures (35% vetch; 35% pea; 15 % barley; 15% triticale) in Meknes/Morocco and (70 % vetch; 30 % triticale) in Siliana/Tunisia. However, the total dry matter of the spontaneous vegetation production between the rows of olive trees were 2.52 t ha<sup>-1</sup> in Meknes region and 2.3 t ha<sup>-1</sup> in Siliana region. Soil water content (w/w) dynamic during growing season changed spatially in response to climate. Indeed, after haying, the soil water content stored at the deepest profile was higher under forage mixtures treatments compared to other treatments. Preliminary results obtained are promising and demonstrated the possibility to intensify the agricultural production system based on olive trees under rainfed conditions through the use of forage mixtures under olive orchards without depleting the soil water content.

### **Evaluating North American elderberry (*Sambucus canadensis*) fodder as silage: effects of packing density and inoculation with lactic acid producing bacteria**

Commercial elderberry production requires complete pruning in late fall to maintain productive canes. For integrated farms (livestock and crops), this biomass has potential as ensiled fodder for ruminant livestock. The objectives of this study were to determine forage nutritive value of late-season (November) pruned elderberry (*Sambucus canadensis* "Rogersville") fodder when ensiled. A 2 x 2 factorial laboratory silo experiment was conducted testing two packing densities with or without inoculation with lactic acid producing bacteria silage inoculant to determine effects on fermentation parameters and silage nutritive values. Pre-ensiled elderberry fodder, composited from plants over 2,000 m<sup>2</sup>, averaged 5.6% crude protein, 62.5% acid detergent fiber (ADF), 72.5% neutral detergent fiber, 11.4% non-fiber carbohydrates, and 53% total digestive nutrients, 52% relative feed value (RVF). The two packing densities were 160.2 kg dry matter (DM)/m<sup>3</sup> and 240.3 kg DM/m<sup>3</sup>. Elderberry fodder was inoculated with SiloSolve FC (CHR Hansen; *Lactobacillus buchneri* LB1819, *Lactococcus lactis* O224; 150 000 CFU/g forage). Packing density did not affect any nutrient characteristics of the ensiled fodder. Though, ADF was greater ( $P = 0.01$ ) in un-inoculated silage, resulting in greater ( $P < 0.01$ ) RFV for inoculated silage. Only lactic acid concentration was affected by packing density with greater concentrations ( $P = 0.04$ ) in high-density silos. Inoculant affected several fermentation parameters with greater concentrations of ( $P < 0.01$ ) propanediol, ( $P = 0.01$ ) propanol, and ( $P < 0.01$ ) acetic acid, while un-inoculated silages had greater concentrations of ( $P = 0.03$ ) NH<sub>3</sub>-N, ( $P < 0.01$ ) lactic acid, ( $P = 0.02$ ) succinic acid, and ( $P < 0.01$ ) ethanol. Overall, late-season elderberry fodder was successfully ensiled, but nutritive value was low. Packing density did not affect nutritive value, but did increase lactic acid concentration. Inoculation improved the RFV by reducing ADF, and though acetic acid production was greater in inoculated silage, total acid concentration was not affected.

Nieman, Christine  
Conway, Ashley

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<p><b>Effect of <i>Grewia optiva</i> and <i>Bauhinia variegata</i> feeding on milking performance of crossbred cows</b></p> <p>Subtropical parts of the India face acute shortage of green fodder in winters. <i>Grewia optiva</i> and <i>Bauhinia variegata</i> are important nutritious fodder tree species which fulfils the green fodder supply during this period. Therefore, the present investigation was conducted at the university dairy farm to evaluate the effect of feeding <i>G. optiva</i> and <i>B. variegata</i> leaves on milking performance of crossbred cows for a period of 90 days. In the study a total twelve crossbred cows were selected on the basis of their daily milk yield and were divided into two groups (G1 and G2) containing six cows in each group. The animals in G1 were fed 10 kg day<sup>-1</sup> animal<sup>-1</sup> <i>G. optiva</i> leaves; whereas, in G2 were fed <i>B. variegata</i> leaves @ 10 kg day<sup>-1</sup> animal<sup>-1</sup> in addition to standard feeding practices of the dairy farm. In order to evaluate the effect of feeding tree leaves, milk yield was recorded daily and milk samples were collected on fortnightly interval for studying milk composition. The study revealed that the feeding of <i>G. optiva</i> leaves to lactating cows resulted in 3.09 per cent higher milk yield and better milk composition (protein%, SNF%, TS%, acidity% and specific gravity) as compared to <i>B. variegata</i> fed group. The overall mean of daily milk yield (kgd<sup>-1</sup>) in G1 (7.67 kgd<sup>-1</sup>) was significantly higher than that of G2 (7.44 kgd<sup>-1</sup>). Average milk protein, SNF, TS, acidity and specific gravity was significantly higher in G1 (3.59%, 8.58%, 12.70%, 0.1371% and 1.0293) as compared to G2 (3.48%, 8.53%, 12.68%, 0.1361% and 1.0280). Milk fat per centage was significantly higher in G2 (4.16%) as compared to G1 (4.12%). The study concluded that the <i>G. optiva</i> was a better fodder species for animal feeding in winters as compared to <i>B. variegata</i> as evident by significantly higher milk yield and composition.</p>	<p>Kishore, Kamal Bishist, Rohit Gautam, Krishan Lal</p>
<p><b>Silvopastures showed better soil quality and growth of southern pines vs. woodlands when both systems were integrated with small ruminants</b></p> <p>Southern pines are important tree species in both silvopasture and woodland systems. Information on the dynamics of soil quality and growth of southern pines in these systems, especially when grazing animals are included in the system, is limited. Hypothesis of the study was that the soil quality and the growth of southern-pine trees would be better in silvopastures vs. woodlands. The study objective was to evaluate the soil quality and growth of southern pines (loblolly, <i>Pinus taeda</i> and longleaf, <i>Pinus palustris</i>) in silvopastures and woodlands. Studies were conducted in silvopastures and woodlands, with six plots in each system (0.4-ha per plot). Silvopastures were developed from the existing woodlands in 2014 by removing the non-pine vegetation, thinning the pines, and planting suitable cool- and warm-season forages. Woodlands consisted of longleaf and loblolly pines, hardwood trees, and several understory plant species. Understory vegetation present in both systems was managed with the rotational stocking of meat goats (Kiko) and hair sheep (Katahdin and Katahdin St. Croix cross). Soil bulk density and moisture were evaluated in 2019 and both plus carbon and nitrogen were measured in 2020. Tree height and diameter at breast height (DBH) were measured from 2018 to 2020. Soil carbon and nitrogen were greater in silvopastures versus woodlands (<math>p &lt; 0.05</math>). Both loblolly and longleaf pines performed better in silvopastures versus woodlands, with a greater DBH (16-35%) and basal area (35-78%) in the former system (<math>p &lt; 0.0001</math>). Tree species showed a significant effect (<math>p &lt; 0.001</math>) on all growth parameters within each system, with loblolly pines having the greater height (6-9%), DBH (27-43%), and basal area (62-107) than longleaf pines. Results show that silvopastures offer a better environment for a faster growth of southern pine trees versus woodlands, when the understory vegetation present in both systems is managed with small ruminants.</p>	<p>Karki, Uma Paneru, Bidur Tiwari, Anand Ellis, Nevershi Bhattra, Shailes Karki, Lila Poudel, Sanjok</p>

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<p><b>Agro-silvo-pasto-fishery: an integrated business model to reduce emission and restore peat degradation in the landscape of peatland in South Sumatra</b></p> <p>Degraded peatland potentially emits high CO<sub>2</sub> from fire and peat decomposition process. Biological peat oxidation emissions reach 4.5 t C ha<sup>-1</sup> yr<sup>-1</sup> in burnt peatland and 7.9 t C ha<sup>-1</sup> yr<sup>-1</sup> in drained peat forest. Using fire for clearing land and drainage peatland through canal-building is a common practice by farmers in Indonesia's peatland. Peat fires that occur yearly during the dry season become a big environmental issue from local to global. On the other side, government policy on zero burning for agricultural practices and rewetting in peatland areas has become a problem for farmers. Agro-silvo-pasto-fishery, a business model that integrated agricultural (low emission practices of paddy field using low emission varieties, intermittent and planting distance regulation, organic fertilizers and zero burning for land preparation) combining with fishpond to rear local species of fish and regulate water. Then, pastural for rearing local varieties of cattle with rotation paddock systems while planting fodder plants and conserving natural regeneration tree species of peat swamp is the concept that we developed in the landscape in Baru Village, where located in Peat Hydrological Unit of Saleh and Lumpur River in Ogan Komering Ilir District, South Sumatra, Indonesia. We apply a circular economic approach in developing an integrated business model of agro-silvo-pasto-fishery through waste management. Livestock waste will be converted to bioenergy for cooking or electricity for domestic use. To promote the zero-burning technique in land clearing, we use biomass for organic fertilizer that can be used by a farmer on their farm or can be sold. Increasing the economic benefit of biomass can reduce the cost of the zero-burning technique. The model was developed based on our data collected through focus group discussion with the community, key informant interviews with local government, literature review, consultation with appropriate experts, and direct observation.</p>	<p>Rahayu, Subekti Manurung, Gerhard Eli Sebastian Fambayun, Rizki Ary Suyanto, S.</p>
<p><b>Integrated livestock and forestry: a case study to reduce operating cost and environmental impact on rubber plantations</b></p> <p>The rubber tree culture (spp) is a long-term investment, the immaturity period of the culture is very long and economic exploitation of the plants can be done only 7 years after implantation, when 50% of the planted area reaches the bleeding technical parameters. The rubber tree is extremely sensitive to the presence of weeds, especially <i>Brachiaria</i> species, due to competition with the planted forest and this threatens Plants development. In the process of implantation and management of rubber forests, the control and/or management of weeds is highly recommended as good practice. The use of pre- and post-emergent herbicides in the crop are usual practices, since the mechanical control carried out with a "hoe" becomes very expensive and of low yield in medium and large plantations. The lack of control and management of weeds negatively impacts the development of the crop, and the continuous use of herbicides in the management causes numerous environmental disturbances, especially in the soil, due to the compaction of areas and contamination of rural catchments. Furthermore the high cost of herbicides application (high agricultural inputs) penalizes small producers. Considering the reduction of environmental impacts and the reduction of the cost of conducting the rubber tree caused by the application of herbicides, the objective of the present work was to test an alternative model to the rubber tree monoculture. With a view to diversification, the use of the area, the reduction of costs and environmental impacts, an integration system was used: Forest x Livestock to control signal grass in the rubber tree crop. The area of the rubber plantation corresponds to 20 hectares, located in the municipality of Itapagipe in the state of Minas Gerais, Brazil. The rubber trees were established between 2014 and 2017, with a spacing of 7 x 2.60 m and received the herd of cattle of the</p>	<p>Costa De Mendonça, Gislaine C. P. Gonçalves, Elaine Abdo, Maria Teresa V.N. Oliveira, Marli D.M. Martins, Mônica Egydio De Carvalho, Renata Martins, Antônio Lúcio Mello</p>

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<p>breed: Milk Caracu from the fourth year after implantation. From December to April, cattle were managed in the rubber tree and, if necessary, in one of the rotated pastures, so that the control of Brachiaria in the rubber tree was done by the cattle grazing and in order to allow the other pasture areas of the property, were fertilized, and remained sealed until the beginning of the dry season. Two and a half years after the implementation of the new cultivation model, there was a 66% reduction in the operational cost for weed control and in the environmental impact, in addition to the model adopted, to have generated as a secondary benefit, savings in the dry season with the purchase of feed for the cattle, since the management of cattle in the rubber plantation allowed the exclusive pasture area (rotated pastures), to have greater rest, and at the time of drought, if they were in excellent conditions to supply the needs of the cattle. The model is a promising alternative to reduce operating costs in rubber production; provide production alternatives for low carbon livestock and contribute to reducing impacts on ecosystems.</p>	
<p><b>SWOT analysis of Livestock sector in Spiti valley of Himalayan cold desert</b> Study was conducted in Spiti valley (310 42'-320 58'N and 77021'-78035' S) of Himachal Pradesh under Trans Himalayan arid zone to investigate the potential and constraints of animal husbandry practices using a strengths, weakness, opportunities and threat analysis framework. Study was conducted by using a semi structured questionnaire by multistage random sampling design in which eight panchayat of Spiti valley were randomly selected, and from each panchayat proportionate number of villages i.e. 2 was chosen and from each village 3 proportionate respondents were considered for the study. On studying the livestock inventory of the selected farmers it was observed that marginal farmers keep more sheep (58.18%) and goat (17.43%) in comparison to large farmers as they are more dependent on pasture lands for grazing. Farmers under marginal category reared minimum number of yaks (2.8%) than small (5.9%) and semi medium (22.7%) farmers as they often face fodder scarcity. Presence of vast livestock biodiversity with the major contribution to the farmer's economy was the great strength to the animal husbandry sector in this region. Farmers in Spiti valley face hardships during winter season as the most of the area is snow bound and the health of animals deteriorates during this season. Inadequate knowledge of improved breeds and scientific breeding methods, lack of knowledge of improved housing systems, scarcity of feed during lean periods, unavailability of veterinary services on time, animal health care during migration, fewer marketing channels of products (milk, meat wool) were the major weaknesses and threats to the system in this region. During last decade ecotourism activities has increased in this region resulting in increased demands of locally available animal products in this region. Therefore, emphasis is required to be paid on animal rearing with higher milk production and manufacturing of pashmina handicrafts for improving the farmer's economy.</p>	<p>Bishist, Rohit Wangmo, Deachen Gautam, Krishan Lal Kishore, Kamal</p>
<p><b>Improvement of plantain leaves nutritive value in goats by urea treatment and nitrogen supplements</b> Plantain (<i>Musa paradisiaca</i>) cultivation leaves a large quantity of residue after harvest which can be used in goats' diets. In order to better assess them, apparent fecal digestibility (Df) of five diets was studied in vivo on 20 castrated Creole bucks, in individual digestibility cage, during three periods using a completely random design. These diets consisted of sun-dried leaves (DL), sun-dried urea treated leaves (DUTL, 5 kg of urea per 100 kg of sun-dried leaves during 90 days with 60 kg of water), protein nitrogen supplemented diet: sun-dried leaves + hoopvine (<i>Trichostigma octandrum</i>, L) leaves (DLH, DL: 61.4% + hoopvine leaves: 38.6%), non-protein nitrogen supplemented diet: sun-dried leaves + urea (DLU,</p>	<p>Fontin, Marie Lesly Audalbet, Bein-Aimé, Beckers, Yves Marlier, Didier</p>

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<p>DL: 98.2%+ U: 1.8%), and fresh leaves (FL). Diets were distributed to meet maintenance needs of the bucks for 21 days included 14 days for adaptation. Offered, left over diets and feces were weighed daily and samples were taken for laboratory analysis. Results showed that intake and Df of DL were very low and allowed only a digestible organic matter (OM) of 9.0 g/kg P0.75, not enough to satisfy maintenance energy requirement in goats. No significant improvement of OM intake and digestibility of plantain leaves was showed with addition of urea, while supplementation of hoopvine leaves allowed a significant increase of intake (from 30.0 to 40.8 g/kg P0.75) and Df (from 29.8% to 40.9%) (<math>p&lt;0.05</math>). However, digestible OM intake for DLH diet was insufficient to meet energy requirement for maintenance. FL diet allowed an OM Df of 40.7%, comparable to DLH. DUTL, which OM Df was 45.1%, was the only diet consumed in sufficient amount to meet the bucks' maintenance needs (22.9 g of digestible OM/kg P0.75). Urea treatment of plantain leaves is the best treatment among those tested for increasing nutritive value of this forage in goats.</p>	
<p><b>Young plantain leaves in weaned rabbit diet: growth performance, digestibility, carcass yield and composition</b></p> <p>Incorporation of young plantain (<i>Musa paradisiaca</i>) leaves (PL) into the diet has been investigated in growing rabbits in order to promote this crop residue use in their diet. Growth performances, carcass weight, yield and composition, chemical meat composition, and digestibility of the diets and PL were evaluated. Four diets, namely PL0, PL20, PL40 and PL60, using four incorporation rates of young PL (0, 20, 40 and 60%, respectively) into a commercial feed as basis, were made. Each diet was given to 8 New Zealand rabbits, 4 males and 4 females, weighing <math>642\pm133</math> g, just after weaning at <math>41.5\pm1.7</math> days, in a random design. The rabbits were housed in individual hutches and fed during 9 weeks, including one week of adaptation. A digestibility trial was conducted during week 4 where feces were weighed daily. Diets offered were weighed daily, while refusals and rabbits were weighed weekly. At the end of the experiment, all rabbits were slaughtered, carcass weight, and composition measured. Diets, refusals, feces, and meat samples were taken to laboratory for analysis. Results showed that adding 20% of PL does not affect intake, average daily gain, feed conversion ratio, final body weight, and carcass weight (<math>p&gt;0.05</math>). However, commercial and reference carcass yield, as well as total meat and dissectible fat percentages were higher in rabbits fed with PL0 diet. Rabbits receiving PL60 diet showed the lowest growth performances; PL40 diet being intermediate (<math>p&lt;0.05</math>). Diets dry matter (DM) digestibility varied from 38.5% for PL60 to 49.3% for PL0 diet (<math>p&lt;0.05</math>). PL DM were digested at a rate between 28.6% and 34.3% according to diets. The meat of rabbits fed with PL60 diet had the lowest fat content (0.4%, against 2.9% in raw product for those consuming PL0 diet). PL can replace 20% of weaned rabbits' diet without modify their growth performances.</p>	<p>Fontin, Marie Lesly Audalbet, Bein-Aimé, Beckers, Yves Marlier, Didier</p>
<h3>O. Agroforestry - an Essential Pillar of Agroecology</h3>	
<p><b>COGEPUR Mali Comités de Gestion Participatif Urgence Reboisement Mali</b></p> <p>Objectif : Réduction de la déforestation et de la dégradation des forêts, protection. Moyens : Par l'agriculture de conservation, écotourisme, développement des groupements d'intérêts économiques (petit élevage, pisciculture, pharmacopée). Conclusion : Assurer une meilleure gestion des réserves et aires protégées ainsi que leurs autonomies financières. - Réduire la pression sur des ressources naturelles limitées et participer au développement</p>	<p>Koné, ABRAHAM</p>



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<p>économique du pays et des communautés locales et à leur développement social, par l'intermédiaire de la réduction de la déforestation et de la dégradation des forêts. - Lutter contre le changement climatique, en réduisant les émissions de GES liées à la déforestation et également à la protection d'autres composantes (sols, climat local, biodiversité). - Mettre en œuvre un modèle d'augmentation de la résilience et d'adaptation face aux changements climatiques.</p>	
<p><b>Urban Agroforestry Topassarinhando: a successful case</b>  The urban agroforestry Topassarinhando was founded in August 2020 with the main objective of attract some birds. The area size is 378 m2 in an urbanized developing region, close to the city of Palmas, capital of Tocantins. The planting was carried out with a small group of friends and neighbors. In addition to forest species, a variety of fruits, flowers and vegetables were added, and it was harvested enough to support a family of 5 people and still donate part of the production. The highlight of the place is the absence of walls, in addition to having informative and playful signs, places to sit under a leafy tree and a compost bin. Additionally, it is common for neighbors and passers-by to visit the place. Due to these characteristics the urban agroforestry has already been subject of a written article for the local news, the G1 website, and an interview for the local TV Anhanguera. The objective of the urban agroforestry is being achieved, since it is notorious the attraction of birds, mainly during drought season (from May to September), attracted by irrigation and existing species. The Instagram account @topassarinhando shows some of these species. A survey of species has also been carried out in the field and about 30 different species were identified in 1 hour of observation. In conclusion, it is possible to re-signify underused urban land, renewing human relationships and stimulating environmental education actions, in addition to positively intervening with beauty and well-being. The biggest difficulties are: 1) the initial need to improve the urban soil, 2) fire, which is very common in the region, and 3) accessibility to the place, because as it has no walls and can be vandalized. In any case, none of the difficulties outweigh the pleasure of caring the area, plants and birds.</p>	<p>Leite, Yanna Fernanda  Marques, Olivia</p>
<p><b>A Win: Win Land Use System for Sustainable Food Production, Nutrition and Health: Evidence from Agroforestry Systems</b>  Blending forestry and agriculture builds human resilience, biodiversity and whole ecosystems. Agroforestry system is regarded as a triple-win practice as it can support food security, mitigate climate change and contribute to adaptation to these changes for a sustainable future. This current trend of agriculture system is making farming system over time unproductive and degraded, putting the long term future of remaining forest cover and farmers related livelihoods in uncertainty. Because of the socio-political and economic dimensions of forest and agriculture, policy makers and smallholder farmers need to be familiar with the trade-offs in removing and retaining shade trees on farms and its impact on yield. The objective of the research is to provide empirical evidence by determining the farmer's perception of agroforestry system, analyze agroforestry adoption and impact of shade levels on yield. The multi stage sampling technique was employed to selected 400 cocoa farmers in the study area. Results revealed that most farmers are small scale farmers as 84% had less than 2 hectares of farms. Other results indicates that 89.5% of farmers strongly agree that cocoa with shade trees gives sustainable yield whiles 10.5% disagree with the accession. All the respondents indicated that cocoa agroforestry offers the potential to develop synergies between efforts to mitigate climate change and efforts to help vulnerable populations adapt to the negative consequences of climate change as well sustainable agriculture production chain. In conclusion agroforestry system emerges as a promising land use option to ensure sustainable food production,</p>	<p>Nunoo, Isaac  Benedicta Nsiah, Frimpong</p>



## VIDEO PRESENTATIONS

<p>nutrition and health. Policies to promote this practice need to ensure training programmes and relevant extension services to educate small farmers across the globe on ecosystem services, climate change adoption strategies and food and nutritional security benefits through the establishment of agroforestry.</p>	
<p><b>Dynamics of agroforestry systems: Bibliometric synthesis of scientific progress</b>  The operational processes of land use systems are increasingly disturbed by the vagaries of the internal or external environment. A response to this situation can be based on system dynamics. To gain a comprehensive understanding of the historical progression and current status, as well as future trends in research on the dynamic aspects of agroforestry, a study was carried out based on the publications of the last 30 years. Using CiteSpace software, using a multi-component bibliometric approach, we extracted bibliometric metadata from 148 publications identified by searching titles, keywords and abstracts for the “Dynamics of Agroforestry Systems” search from the Scopus database. The results show that dynamic studies represent only 2.27% of global scientific production on agroforestry systems. According to the keywords and co-occurrence networks that were generated, the thematic areas in which most publications on agroforestry systems were found are “Forestry” and “Agronomy” up to 2010. Conversely, on for the 2010-2021 period, the dominant categories are “Environmental Sciences” and “Geosciences”. According to the exploded references, land-use change, carbon sequestration, use of GIS, climate change and ecosystem services were identified as hot research questions in the field. Additionally, a keyword co-occurrence analysis identified “Land use change”, “modeling in the management of agroforestry systems” and “environmental accounting or environmental taxation” as important future research directions that deserve further attention.</p>	<p>Ahissou, Mèssètin Vital  Assede, Eméline Sèssi Pélagie  Biaou, Samadori Sorotori Honoré</p>

