



Laboratoire de Biomathématiques &
d'Estimations Forestières

ANNUAL REPORT

2025



04 BP 1525 Cotonou, Benin

Tel. +229 958-408-00 | Fax. +229 21 36 01 22

www.labef-uac.org

Editor

Laboratoire de Biomathématiques et d'Estimations Forestières

University of Abomey-Calavi

04 BP 1525 Cotonou, Benin

Tel. +229 01958-408-00

Fax. +229 213-0601-22

www.labef-uac.org

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Prepared by:

Guillaume Hounsou-Dindin

David Akodekou

Yanik Akin

Constant Gnansounou

Marcel Donou

Kolawolé Valère Salako

Romain Glèlè Kakaï



Natural regeneration of *Mimusops andongensis* monitored in a study of natural regeneration dynamic in the Lama forest reserve, Southern Benin.

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Acknowledgements

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Abbreviations & acronyms

ACE-MSA	: African Excellence Center for Mathematics Sciences and Application
AGNES	: African German Network of Excellence in Science
AGriDI	: Accelerating inclusive green growth through Agri-based Digital Innovations in West Africa
AI	: Artificial Intelligence
BMBF	: Federal Ministry of Education and Research
DAAD	: Deutscher Akademischer Austauschdienst
EU	: European Union
FAO	: Food and Agriculture Organization
FCDO	: Foreign, Commonwealth & Development Office
HRH-SEMCA	: Socio-Ecological Modeling of COVID-19 dynamics in Africa
IF	: Impact factored journals,
INRAB	: National Institute of Agricultural Research of Benin
LABEF	: Laboratoire de Biomathématiques et d'Estimations Forestières
MBIOST	: Master in Biostatistics
ML	: Machine Learning
MsC	: Master of Sciences
NGO	: Non-Governmental Organizations
OWSD	: Organization for Women in Science for the Developing world
PhD	: Doctor of Philosophy
PNLP	: National Malaria Control Programme
RUFORUM	: Regional Universities Forum for Capacity Building in Agriculture
TWAS-IsBD	: The World Academy of Science - Islamic Development Bank
UAIML	: Unit of Artificial Intelligence and Machine Learning
UBM	: Unit of Biomathematics
UFE	: Unit of Forest Estimations
UNDP	: United Nations Development Programme
USD	: United States Dollar
WafriCLP	: West African Climate Leadership Program for Women
WIF	: Without impact factor journals

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Statement of the head of the Lab

Dear colleagues and friends,

I am delighted, as usual, to introduce the 2025 annual report of the “Laboratoire de Biomathématiques et d’Estimations Forestières” (LABEF). There has been significant progress of team members, and we have attracted several Bachelor and Master’s students, PhD-students, post-docs, and visiting researchers in our research units.

Thanks to the commitment of our members, we have sustained our standards in terms of scientific research. Although we still have room for improvement, I would like to take this opportunity to congratulate all the members on their efforts and contributions to increasing the visibility of the laboratory through the quality of our research and its relevance to society.

LABEF will continue to make biostatistics, climate change and biodiversity conservation a priority of its research themes to inform and guide stakeholders. Mathematical modelling in Forestry has remained a priority of our research agenda, and this has been extended to the field of Epidemiology. Furthermore, with the growing AI tools, Precision Agriculture is now part of LABEF's research portfolio, and we are making progress in developing ML & AI tools for diseases detection, yield prediction, and biomass estimation.

Enjoy reading this report, and I look forward to sharing with you the future progress of LABEF.

Prof. Romain GLELE KAKAI
Head of LABEF



A woodland of *Isoberlinia doka* and *Isoberlinia tomentosa* in the Wari-Maró forest reserve. © LABEF

CHAPTER 1.

LABEF: Overview and Team

1.1. Mission, vision, and objectives of LABEF

Created on 27th May 2014 by Romain GLELE KAKAÏ, Professor in biometry and forest estimations, the “Laboratoire de Biomathématiques et d’Estimations Forestières”, is part of the “Ecole d’Aménagement et Gestion de l’Environnement”, Faculty of Agronomic Sciences, University of Abomey-Calavi.

The Laboratory aims to:

- raise awareness of the importance of Mathematics, particularly Statistics in Biological Sciences;
- analyze the applicability of mathematical tools in life sciences with a particular focus on understanding the interactions between ecological processes, anthropogenic factors, and terrestrial ecosystems' structure to deliver clear management actions and policies.

The mission of LABEF is to enhance understanding of biological systems through the effective use of biomathematics.

Its vision is to be, by 2030, a leading institution in developing mathematical tools for biologists and supporting decision-makers in forestry for a better society.

1.2. Organization of LABEF

LABEF is organized into four departments, including the (i) fundraising department, (ii) social life department, (iii) administrative department, and (iv) research department. The research department now includes three units, namely: Unit of Biomathematics (UBM), Unit of Artificial Intelligence and Machine Learning (UAIML), and Unit of Forest Estimations (UFE).

- **The Unit of Biomathematics (UBM)** deals with biology and mathematics and is interested in applications of mathematics in biology. This unit is interested in the use of mathematical theories in biology and especially in publishing scientific notes describing the application of different mathematical tools in life sciences.
- **The Unit of Forest Estimations (UFE)** falls into the overall perspective of assessing wood resources, biomass, and carbon stock available in forest ecosystems. The Unit is interested in developing accurate and robust methods and models for estimating forest resources. It is equally interested in understanding ecological processes and patterns and developing clear and applicable management policies for forest managers and decision-makers. The unit also investigates forest governance approaches, effectiveness, replicability, socio-economic and ecological outcomes, decision-making process, and benefit-sharing.
- **The Unit of Artificial Intelligence and Machine Learning (UAIML)** aims to operationalize and develop machine learning (ML) and artificial intelligence (AI) methods to assist innovation in the field of biology, particularly Forestry and Agriculture.

1.3. Research topic covered at LABEF

The ecosystem of research topics covered at LABEF is diverse and illustrated in figure 1.

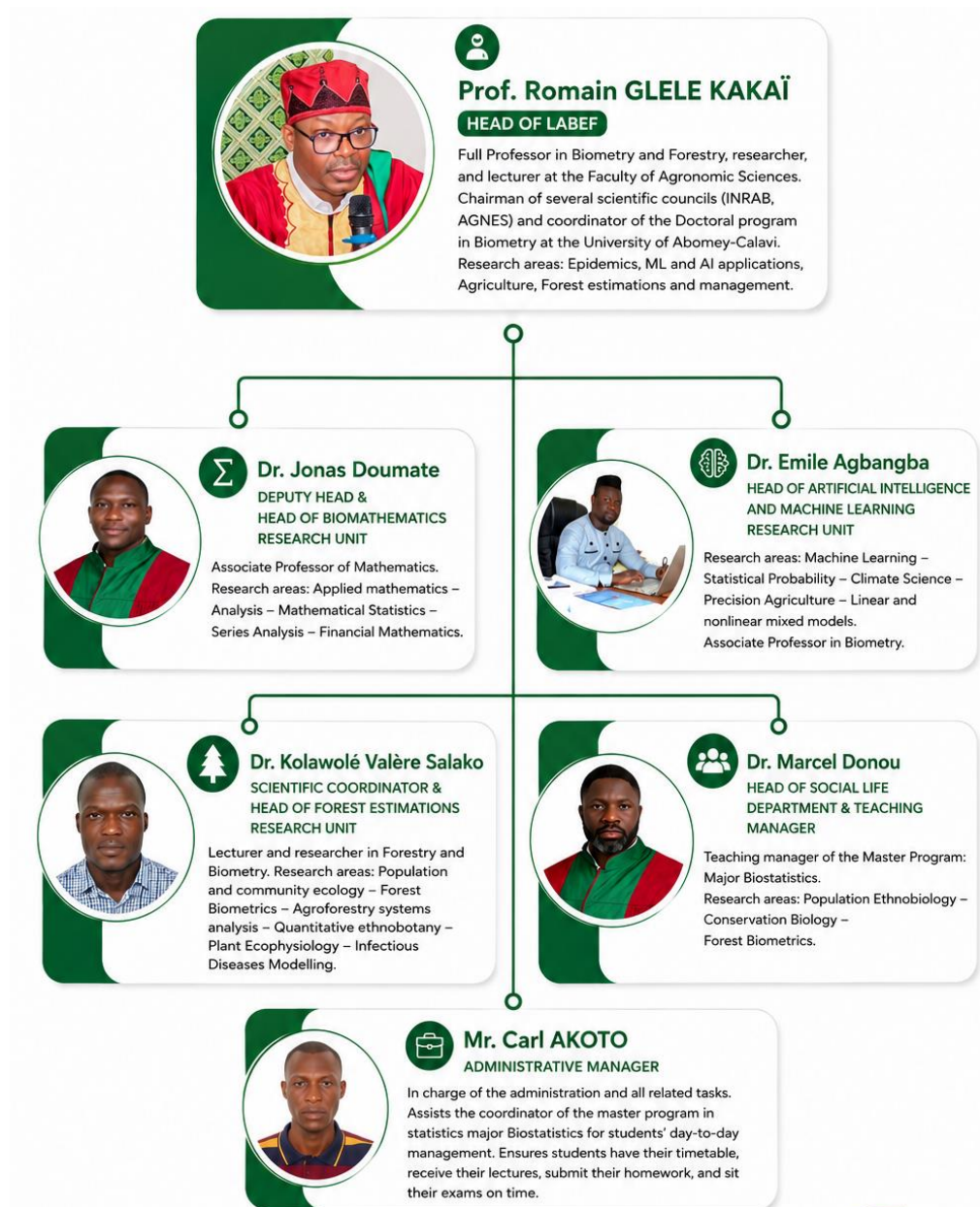


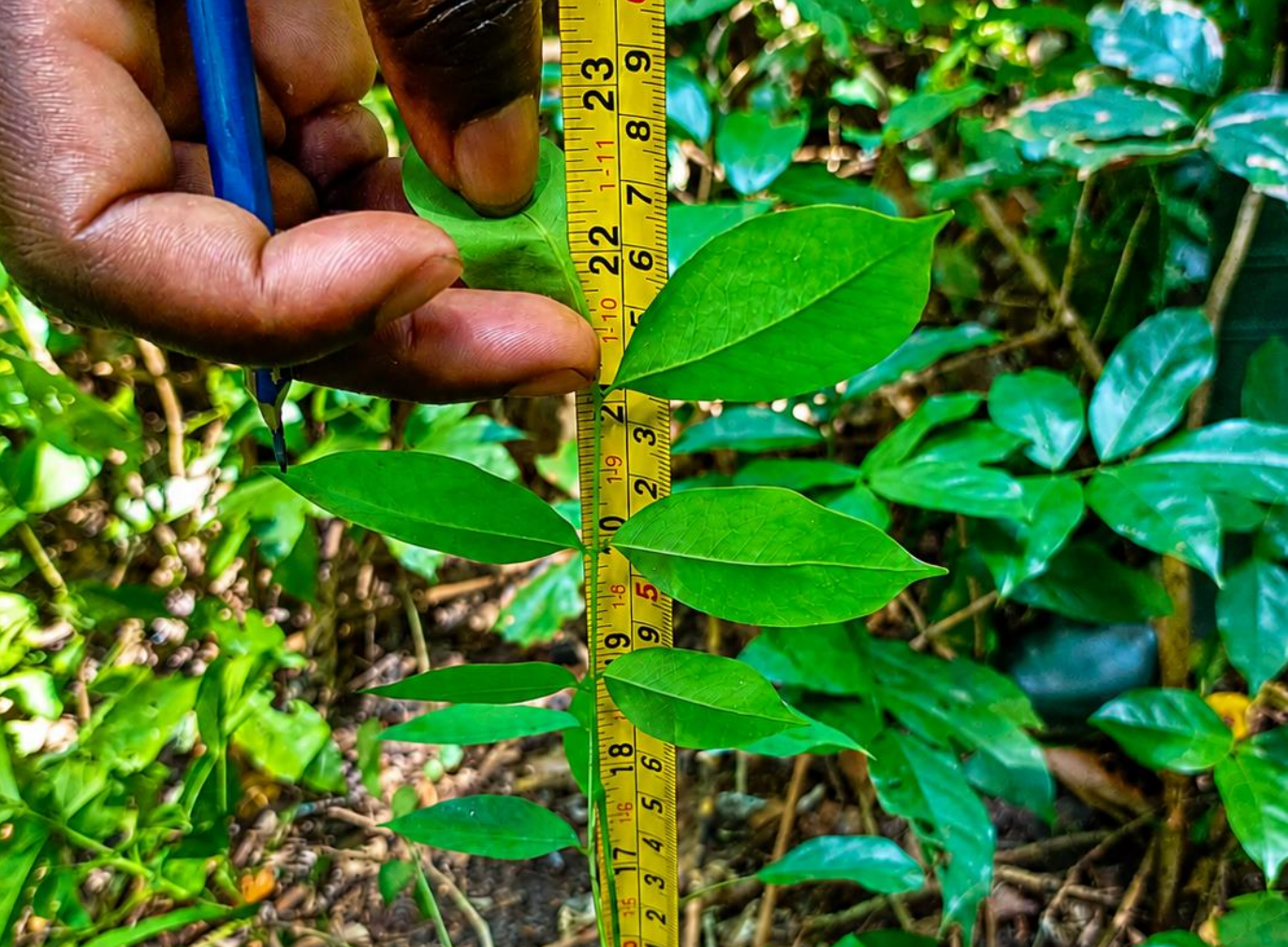
Figure 1. Overview of research topics covered at LABEF

Our work contributes to six Sustainable Development Goals (SDGs).



1.4. The core management team of LABEF in 2025





A seedling of *Azelia africana* monitored in a reciprocal transplantation experiment for assessing the species local adaptation to drought in the Lama Forest Reserve. © LABEF

CHAPTER 2.

RESEARCH: Milestones & Highlights

2.1. Scientific publications in 2025

2.1.1. Publications Milestones

In 2025, LABEF produced a total of 57 scientific publications in peer-review journals. Among these publications, 98.24% were scientific publications in peer-review journals (56 published papers), and 1.75% were books and book chapters (1 document) (figure 2).

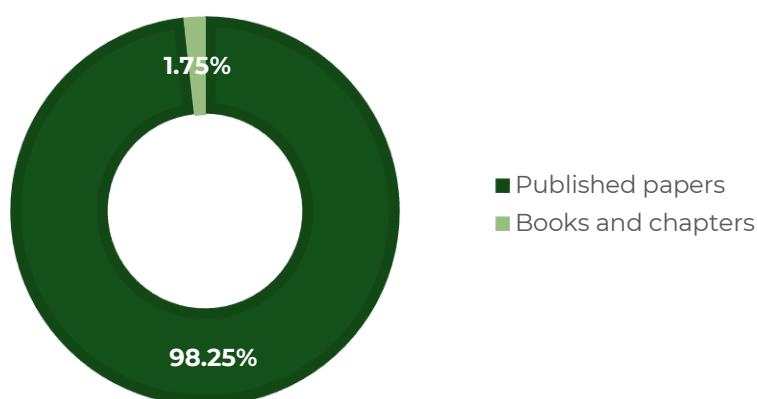


Figure 2. Scientific publications produced by LABEF in 2025

2.1.2. Diversity of Journals and scientific disciplines covered by publications of LABEF in 2025

In 2025, the scientific articles were published in 49 journals as summarized in table 1. Several research domains were covered. Among the sixteen research domains covered, Forestry (20 published papers), Ecology (9 published papers), and Biometry (7 published papers) were the most investigated (figure 3).

Table 1. Diversity of journals for published, in press, and under review papers

Journals	Type of journals	Impact factor (IF)	Number of papers
African Journal of Ecology	IF	1.1	2
Agroforestry Systems	IF	2.2	2
Biological Conservation	IF	4.4	1
Biostatistics&Epidemiology	IF	1.3	1
Conservation	IF	1.9	1
Discover Sustainability	IF	3.0	1
Diversity	IF	2.1	1
Ecological Informatics	IF	7.3	1
Ecology, and Landscapes	IF	3.7	1
Frontiers in Ocean Sustainability	IF	2.3	1
Frontiers in Sustainability	IF	2.9	1
Functional Ecology	IF	5.1	1
Genetic Resources and Crop Evolution	IF	1.9	1
Global Ecology and Conservation	IF	3.4	3
Heliyon	IF	3.6	1
Human Ecology	IF	1.7	1
Infectious Disease Modelling	IF	2.5	1
International Journal of Disaster Risk Reduction	IF	4.5	1
Journal for Nature Conservation	IF	2.5	1
Journal of Environmental Management	IF	8.4	1
Journal of Ethnobiology and Ethnomedicine	IF	1.3	1
Journal of Probability and Statistics	IF	1.3	2
JP Journal of Biostatistics	IF	0.1	1
Maritime Studies	IF	2.3	1
Modeling Earth Systems and Environment	IF	2.9	1
Nature Communications	IF	15.7	1
Ocean & Coastal Management	IF	5.4	1
PLOS ONE	IF	2.6	1
Remote Sensing Applications: Society and Environment	IF	4.1	1
Restoration Ecology	IF	2.7	1
Scientific African	IF	3.3	1
Trees, Forests and People	IF	2.9	3
Wetlands	IF	2.0	1
Wetlands Ecology and Management	IF	1.6	1
African Journal of Applied Statistics	WIF	0.1	1
Bulletin de la Recherche Agronomique du Bénin (BRAB)	WIF	-	1
Climate Change, Food Security, and Land Management	WIF	-	1
Discover Agriculture	WIF	-	1
Discover Applied Sciences	WIF	-	1
Discover Artificial Intelligence	WIF	-	1

Journals	Type of journals	Impact factor (IF)	Number of papers
Discover Plants	WIF	-	1
EcoEvoRxiv	WIF		1
Environmental Challenges	WIF	-	1
Ethnobotany Research and Applications	WIF	-	2
Genetic Resources	WIF	-	1
Mathematical Biosciences and Engineering	WIF	-	1
Next Research	WIF	-	1
Telecommunications Engineering	WIF	-	1
Wetlands of Tropical and Subtropical Asia and Africa: Biodiversity, Livelihoods and Conservation	WIF	-	1

IF = Impact factored journals, WIF = Without impact factor journals

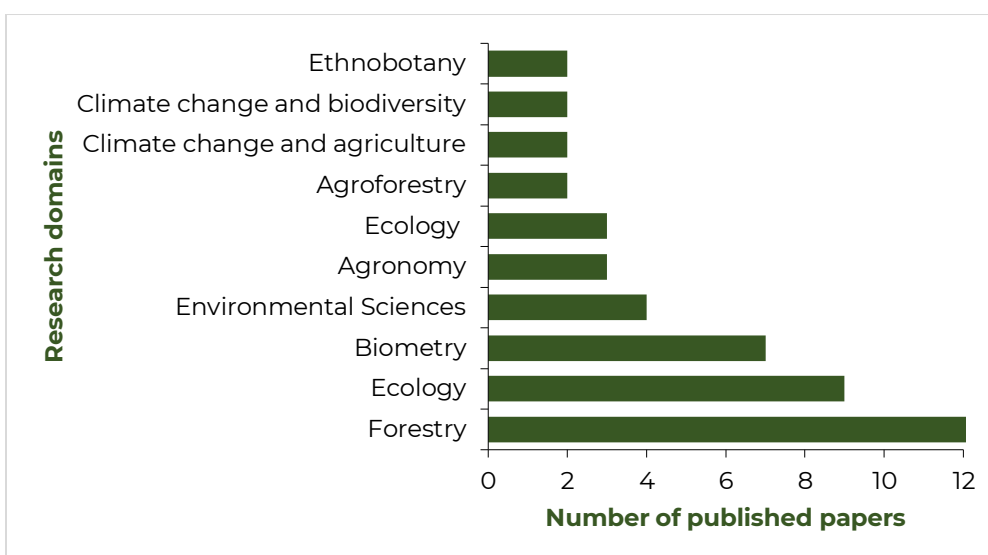
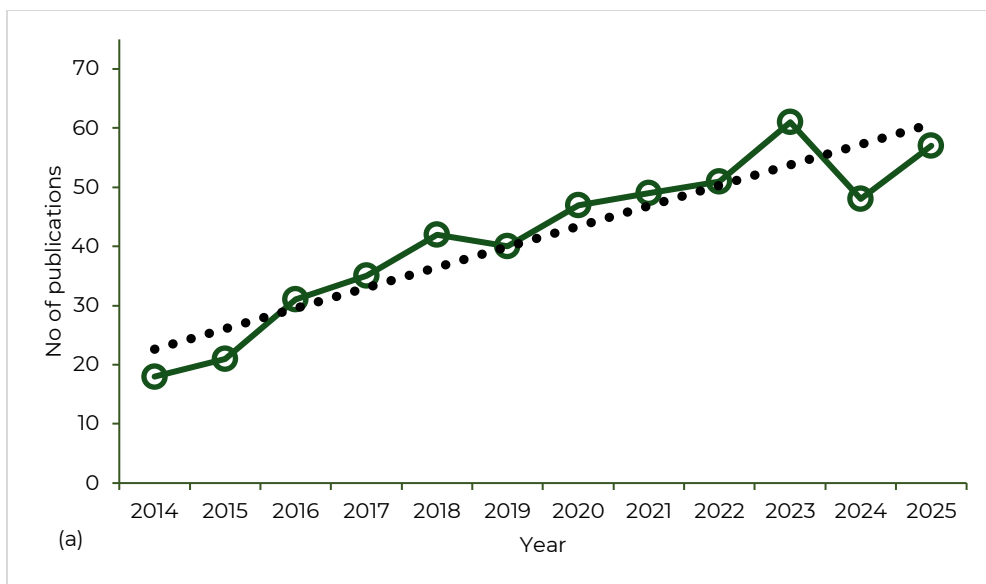


Figure 3. Diversity of research domains for published papers by LABEF in 2025

2.1.3. Performance and highlights in publication

LABEF produced slightly more scientific articles in 2025 than in 2024 (figure 4a). Among the 57 scientific publications in peer-review journals of 2025, 40 publications (70.18%) were published in journals with an impact factor (figure 4b).



(b)

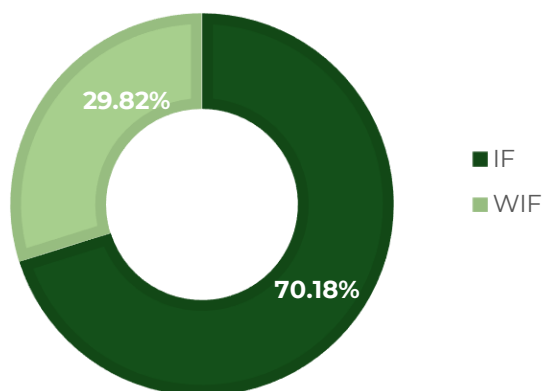


Figure 4. Trends in annual publications from 2014 (a), and quality of publications (b)

Among the papers published in peer-review journals with an impact factor in 2025, 62.50% were in journals with an impact factor between 2 and 5 (figure 5).

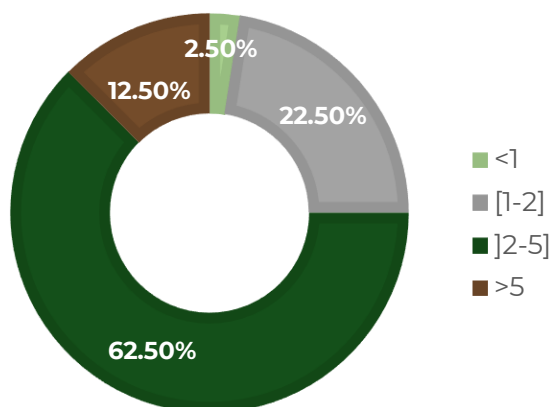


Figure 5. Range of impact factors of published papers

2.1.4. Authorship and leadership position in publications in 2024 and 2025

For the 57 scientific papers published in 2025, members of LABEF have occupied variable positions. Members of the lab were exclusively the first author in 11 published papers (19.30%). In nine of the published papers, members of LABEF were among the first three authors. The leadership (last) position was occupied by members of the lab in one quarter of the published papers (figure 6).

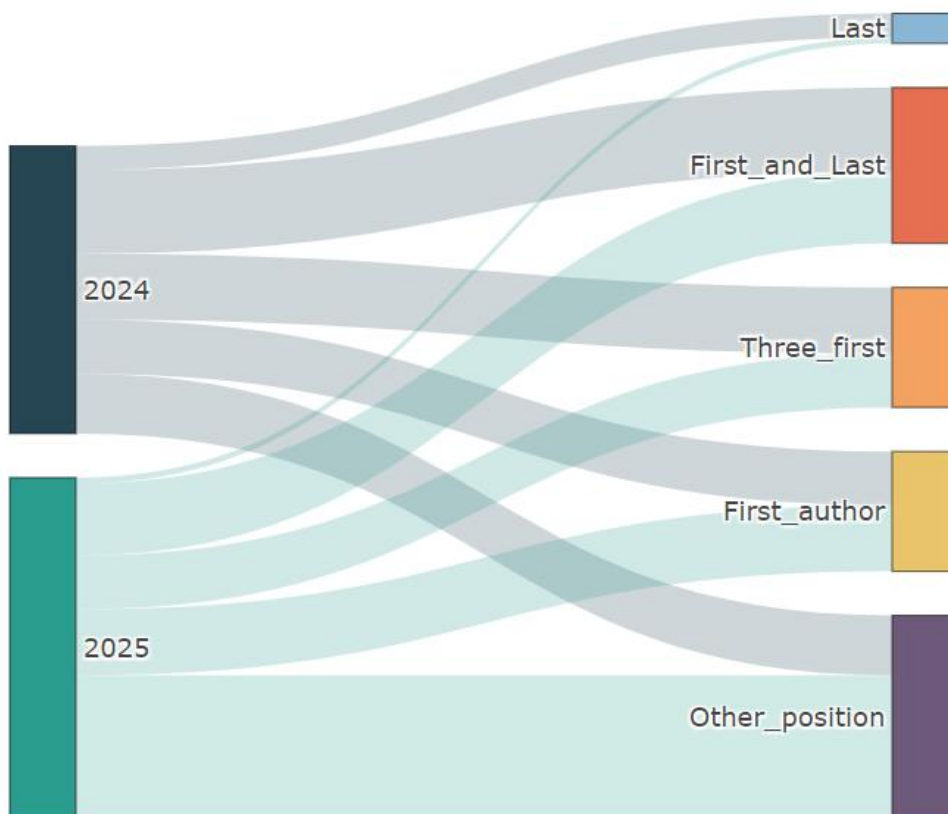


Figure 6. (Co-) Authorship position of LABEF members in publications in 2025

2.2. Research projects in 2025

The research projects implemented by LABEF in 2025 included, as usual, small, medium, and large grants. Nine individual small grants or PhD/Post-doc fellowships were implemented by members of LABEF in 2025 (see table 2).

Table 2. Individual fellowships and small research grants in LABEF in 2025

N°	Funder	Recipient	Type	Status
1	British Ecological Society	Enagnon Bruno Lokonon	Small grant	Ongoing
2	European Union (EU) student exchange programme. Erasmus+	Mirabelle Gandji	Phd Research Fellowship	Ongoing
3	Organization for Women in Science for the Developing world (OWSD) and Centre d'excellence Africain en Sciences Mathématiques et Applications (CEA-SMIA)	Rachidatou Orounla	Phd Research Fellowship	Ongoing
4	ANSO-CAS-TWAS/UNESCO	Moustapha Arèmou Kolawole	PhD Research Fellowship	Ongoing
5	DAAD	Traore Kassifou	PhD Research Fellowship	Ongoing
6	Alexander von Humboldt Foundation	Dr. Corine B. Laurenda Sinsin	Post-doc Research Fellowship	Ongoing
7	Alexander von Humboldt Foundation	Dr. Guillaume Hounsou- Dindin	Post-doc Research Fellowship	Ongoing
8	Make Our Planet Great Again	Dr. Mahoutin Gildas Serge Zanvo	Post-doc Research Fellowship	Ongoing
9	Sub-Saharan African Consortium for Advanced Biostatistics (SSACAB)	Dr. Souand Peace Gloria Tahi	Post-doc Research Fellowship	Ongoing

One medium and six large research projects have been implemented in LABEF in 2025 (Table 3). In the frame of these projects, LABEF partnered with several institutions from diverse countries in Africa (Ghana, DRC,

Malawi, Tanzania, South Africa), and Europe (Germany, United Kingdom). For more details on these projects, please visit our website ([LABEF](https://www.labef.org))

Table 3. Ongoing small, medium and large research projects in LABEF in 2025

N°	Project title	Project type	Funding institution	Status
1	Blue carbon and economy in West Africa: mobilizing datasets to better understand mangrove health in relationship to climate change	Medium	LACUNA	Ongoing
2	DAAD "In-Country/In-Region Scholarship Programme" for Master in Statistics (Major Biostatistics) & Doctorate in Biometrics.	Large	Deutscher Akademischer Austauschdienst German Academic Exchange Service (DAAD)	Ongoing
3	Socio-Ecological Modeling of COVID-19 dynamics in Africa (HRH-SEMCA)	Large	Alexander von Humboldt	Ongoing
4	Valorization of Pineapple Residues for Soil Fertility Management and Energy Autonomy in Benin	Large	VLIR-UOS-COLEAD	Ongoing
5	Digital-assisted smart integrated agroecological maize pest <i>Spodoptera frugiperda</i> management in Benin	Large	Ekhagastiftelsen	Ongoing
6	DELTAS Africa II. Sub-Saharan Africa Consortium for Advanced Biostatistics training.	Large	Wellcome and the United Kingdom's Foreign, Commonwealth & Development Office (FCDO)	Ongoing
7	Accelerating inclusive green growth through Agri-based Digital Innovations in West Africa (AGriDI)	Large	Agropolis fondation	Ongoing

2.3. Master, and Ph.D. degree dissertations in 2025

Twenty-six (26) MSc students (11 women and 15 men) completed their MSc degree in biostatistics or natural resources management at LABEF in 2025 (figure 6, Appendix A1.3).

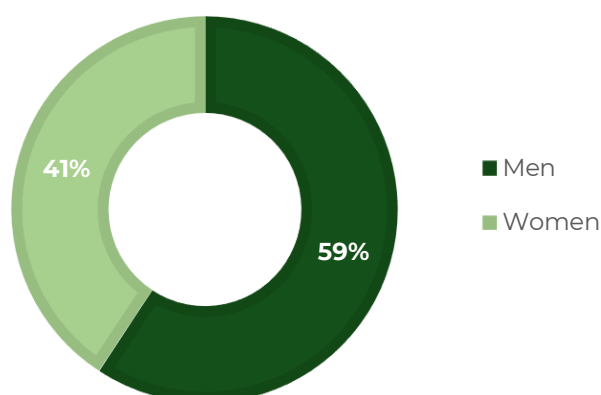


Figure 7. Gender balance for Master theses

Regarding the Ph.D. students in 2025, eight students (4 females and 4 males) defended their theses in biometry, Climate change and biodiversity, Climate change and Agriculture, and Natural resources Management. Sixteen PhD theses are ongoing (6 females and 10 males). These Ph.D. initiatives covered several research domains, with biometry being the most investigated discipline (11 initiatives, see figure 7a). Moreover, 58% of the Ph.D. students are at least in their third year in 2025 (figure 7b).

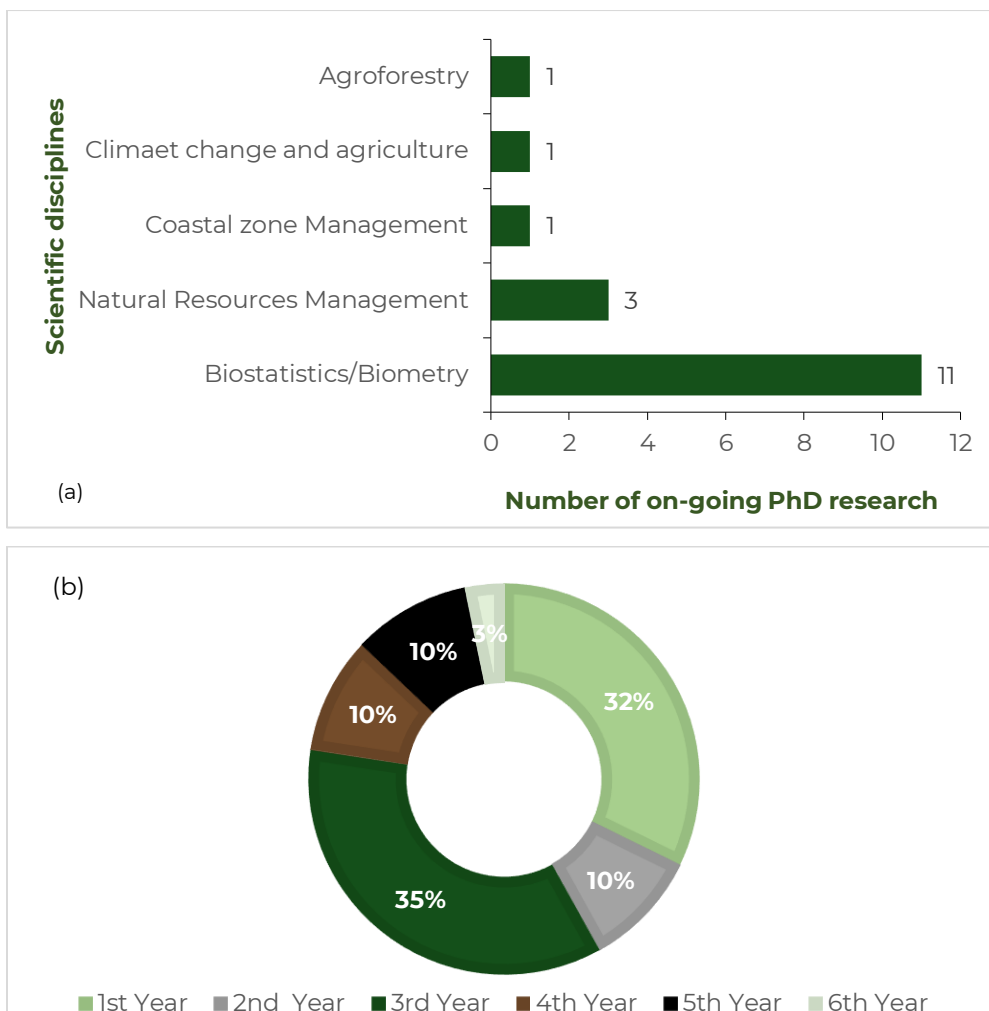


Figure 8. Fields of research (a) and stages of ongoing Ph.D. theses in 2025

2.4. Scientific distinctions in 2025

In 2025, LABEF researchers and early-career scientists received several prestigious fellowships and scientific distinctions, reflecting the quality and growing visibility of the laboratory's research activities at national, regional, and international levels.

AWARD Fellowships.

Six postdoctoral researchers and Ph.D. students affiliated with LABEF, namely

Dr Ariane Houetohossou, Dr Clarisse Dété, Dr Souand Tahi, Mrs Mirabelle Gandji, Paulette Guedezeoume, and Consolas Hodonou were selected for

AWARD African Women in Data Science Fellowships in 2025. This recognition provides an important

opportunity to strengthen their scientific skills, leadership capacities, and professional networks, while contributing to the advancement of research and innovation in Africa.



African Women in Data Science Fellowship



Election of Professor Romain Glèlè Kakaï to the African Academy of Sciences (AAS).

This distinction recognizes his scientific contributions and further enhances the visibility of LABEF within the African and international scientific community.



29th March 2025

University of Abomey-Calavi

Dear Prof. Romain Lucas GLELE KAKAI AGBIDINOUKOUN,

RE: Your Election to the African Academy of Sciences Fellowship

The Governing Council of the African Academy of Sciences (AAS) has made its decision on nominations that were submitted for (year) AAS Fellowship and I am pleased to inform you that you are now an elected Fellow of the African Academy of Sciences (AAS). This is based on a series of reviews conducted at various levels following your nomination. The AAS Fellowship recruitment, follows a rigorous evaluation by the AAS Membership Advisory Committees (MACs) in various fields of specialization. The penultimate step prior to the voting by Fellows of the Academy was the decision by the Governing Council. The recommendations of the MACs and the votes by the Fellows were compiled and submitted to the AAS Governing Council for final review and endorsement.

Accordingly, I take this opportunity to congratulate you on the success of your election to the AAS Fellowship. You can proudly display this recognition by adding 'FAAS', after your name and/or signature.

We look forward to welcoming you at the next General Assembly Meeting (GA) where you will be inducted and receive your Certificate of Fellowship.

AUF Scientific Award

Dr. Kolawolé Valère Salako received a **2025 Scientific Award from the Agence Universitaire de la Francophonie (AUF)**, in recognition of the quality and contribution of his scientific work. This distinction further highlights the recognition of LABEF researchers within the Francophone academic and scientific community.



Affilié à 54
Etats
membres
et 10
observateurs
associés
dans 110
pays
et territoires
d'outre-mer
et 100
universités
et centres
de recherche
et d'enseignement
supérieur
dans 110
pays et
territoires
d'outre-mer
et 100
universités
et centres
de recherche
et d'enseignement
supérieur

Paris, le 22 octobre 2025

Monsieur Kolawolé Valère SALAKO
Université d'Abomey-Calavi
Cotonou - Bénin
salakovalere@gmail.com

Objet : Prix de la Francophonie pour Jeunes Chercheurs – Édition 2025

Monsieur,

J'ai le plaisir de vous annoncer que le Conseil scientifique de l'Agence Universitaire de la Francophonie (AUF), sur proposition du Jury chargé de l'évaluation des dossiers de candidature, m'a proposé de vous attribuer le Prix de la Francophonie pour jeunes chercheurs, édition 2025, option « Sciences et Technologies ». Je me réjouis de cette proposition que je confirme.

Vu la qualité de vos travaux dans le domaine de la foresterie, écologie, ethnobotanique, domestication des fruits et de la biostatistique, le Conseil scientifique a également proposé, que vous fussiez désormais partie des experts de l'AUF. À ce titre, nous serions heureux de vous solliciter dorénavant pour des missions d'expertise dans le champ de vos compétences.

Vous recevrez dans les prochains jours un courriel afin de vous communiquer toutes les informations relatives à la remise du prix.

En vous réitérant toutes mes félicitations, je vous prie de croire, Monsieur, à l'assurance de ma considération distinguée.



A common garden experiment testing responses of different provenances of *Afzelia africana* to water stress at the experimental site of LABEF at Sékou.
© LABEF

CHAPTER 3.

RESEARCH: Connection, and networking

3.1. Collaboration for publication in 2025

In 2025, LABEF collaborated with researchers from 53 countries, national collaborations being the most dominant (34.28%, figure 9a). The most represented continent for these collaborations was Africa more than 54.96%, followed by Europe more than 20.11% (figure 9b).

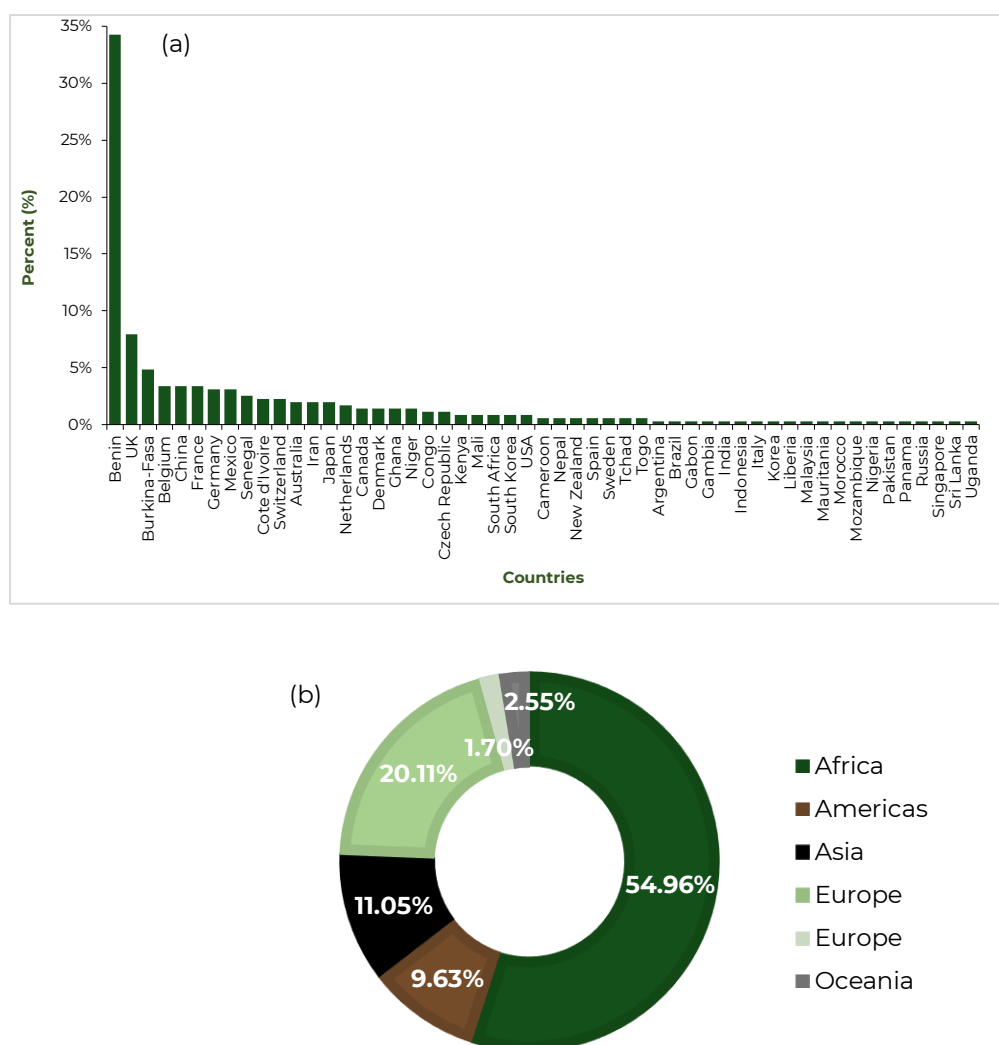


Figure 9. Countries (a) and world regions (b) of co-authors of publications of LABEF in 2025

3.2. Visiting researchers at LABEF in 2025

In 2025, LABEF hosted a contact visit by the ULB-Cooperation team. The ULB-Cooperation team came to learn more about our research on mangroves. We explored future collaboration between LABEF and ULB Cooperation team.





Photo of participants in a data analysis training workshop organised by LABEF. © LABEF

CHAPTER 4.

Capacity building

4.1. Graduate program in Biostatistics (MBIOST)

4.1.1. Presentation of the MBIOST

Since its creation in May 2014, LABEF has been running an international graduate program in Biostatistics. This master's program offers extensive and unique training in recent statistical methods and tools for their applications in Life sciences. At the end of the training, graduated students can easily go into professional life as Biostatisticians or engage in research in Biostatistics by integrating into a doctoral school. This training is open to holders of a Bachelor Degree in Life Sciences (agronomy, health, biology, environment, etc.), or in Mathematics/Statistics or Master, Degree holders wishing to acquire knowledge and know-how in the field of data collection, management, and analysis. The Master programme in Biostatistics has already trained and released ten batches of skilled biostatisticians and data analysts. The 12th batch of students started in September 2025 and enrolled 33 students from 07 countries (Benin, Burundi, Congo, Ethiopia, Kenya, Rwanda and Tanzania). To date, 211 students have been trained. The program has been supported by several programs in the past (e.g., Intra-ACP Academic Mobility Programs). Currently, it is supported by, the German Federal Ministry of Education and Research through DAAD In-Country/In-Region Program, the African Excellence Center for Mathematics Sciences and Application (ACE-MSA, through World Bank Group fund), and the DELTAS Africa II Sub-Saharan Africa Consortium for Advanced Biostatistics training.

4.1.2. Aims of the MBIOST

The MBIOST program aims to provide Food Enterprises, Projects, Health Sector (Units of Clinical research), Department of Medical Information, etc.), Public and Private Research Institutions, Non-Governmental Organizations (NGO), International Organizations (FAO, UNDP, World Bank, etc.),

Education and International Research Institutions, talented Biostatisticians and data analysts. The abilities this training gives in data collection, data management, statistical analysis, and valorisation allow graduates to practice the job of Biostatisticians in charge of Statistical Studies in various sectors. Our alumni work as data scientists and Statisticians in multiple institutions (e.g., AfricaRice, MTN, Global Fund TB, Benin National Institute of Agricultural Research, University of Malawi, University of Abomey-Calavi) and PhD-students or post-docs in Africa, Europe, Asia, and America.

4.1.3. How to apply?

Visit the website ([LABEF](#)) and fill in the online application form ([Application-form](#)). Candidates from Benin could submit their applications to the secretary of the program, located at the Laboratoire de Biomathématiques et d'Estimations Forestières. Please visit the webpage of the Master for detailed information ([LABEF-Master](#)).

4.2. Doctoral program in Biometry

Since 2017-2018, the Doctoral School of Agronomic and water Sciences has been offering a PhD program in Biometry under the coordination of Prof Romain GLELE KAKAÏ (the head of LABEF and coordinator of the master's program in Biostatistics). Thus, to date, 37 students are enrolled in the PhD program, 5 defended their thesis in 2025 (see appendix 1) while 10 have already graduated.



Group photo of participants to the workshop on the inclusion of small-scale rural women farmers in the teaching of local ecological solutions for climate change adaptation in Sub Saharan Africa. © LABEF

CHAPTER 5.

Services to community and society

In 2025, LABEF contribution to community and society included two scientific seminars, four technical and expertise support to national environmental projects and governance initiatives, and one capacity building for the inclusion of small-scale rural women farmers in the teaching of local ecological solutions for climate change adaptation.

5.1. Seminar on Artificial Intelligence in Service of Research and Education



The scientific seminar organized by LABEF on the topic *“Artificial Intelligence (AI) for Research and Education: Challenges, Ethics, Responsibility, and Applications”* highlighted that AI is not a

panacea. Behind every well-crafted prompt lies a clear intention, a structured thought process, and an intelligent capacity to engage meaningfully with the machine to realize its full potential. The seminar attracted approximately 272 participants, including students, academic researchers, and civil society actors. Of these, 60 attended in person, while the remainder joined online. Prof Idy Diop, (Telecommunications Engineering, IOT, Computer Science) from the Department of Computer Engineering Professor, Université Cheikh Anta Diop, Senegal and Paul Ablo Igor HOUNZANDJI (AI, ML, forestry, environmental science), Director - *Agence Francophone de l'Intelligence Artificielle (AFRIA)*, Montreal, Canada were the guest speakers at this seminar.

5.2. Seminar on Structural Equation Modeling (SEM) using R



LABEF-UAC organized a three-day training seminar on “Structural Equation Modeling

(SEM): Principles and Applications in Health, Environment, and Agronomy using R”. The seminar began with exploratory and confirmatory factor analyses, combining theoretical explanations with hands-on exercises in R. Subsequent sessions covered advanced SEM concepts, estimation methods, and model evaluation, with a strong focus on practical applications. Approximately 30 participants attended in person, while 150 attended online, including both national and international participants. This training was supported by the Sub-Saharan African Consortium for Advanced Biostatistics (SSACAB).

5.3. Participation in the second 2025 session of the National Steering Committee of the mangrove resilience project

LABEF participated in the second 2025 session of the National Steering Committee of the mangrove resilience project, contributing scientific and technical expertise toward the sustainable management and restoration of mangrove ecosystems in Southern Benin. The laboratory also took part in field visits organized in the mangrove landscapes of Sèmè-Podji, Ouidah,

Comè, and Bopa to assess ongoing restoration activities and support evidence-based decision-making.

5.4. Contribution to the completion of the management and conservation plans for mangroves

LABEF contributed to the workshops dedicated to the finalization of management and conservation plans for mangrove landscapes, as well as to the development of a capitalization document on environmental information and knowledge. Through these activities, the laboratory supported national efforts aimed at biodiversity conservation, ecosystem restoration, climate resilience, and sustainable natural resource management.

5.5. Validation workshop for the National Forest Inventory methodology

LABEF participated in the validation workshop for the National Forest Inventory (NFI) methodology and the presentation of the NFI database model, held from July 23 to 24, 2025, in Bohicon. Organized by the Ministry of Environment and Transport in collaboration with the FAO under the REDD+ Project, this workshop allowed the laboratory to provide technical insights into forest monitoring and data management. This contribution supports Benin's strategic efforts in sustainable forest management and accurate evaluation of national forest resources for evidence-based conservation and management planning.

5.6. Participation in the support mission for the preparation of the SCALE-Benin Project

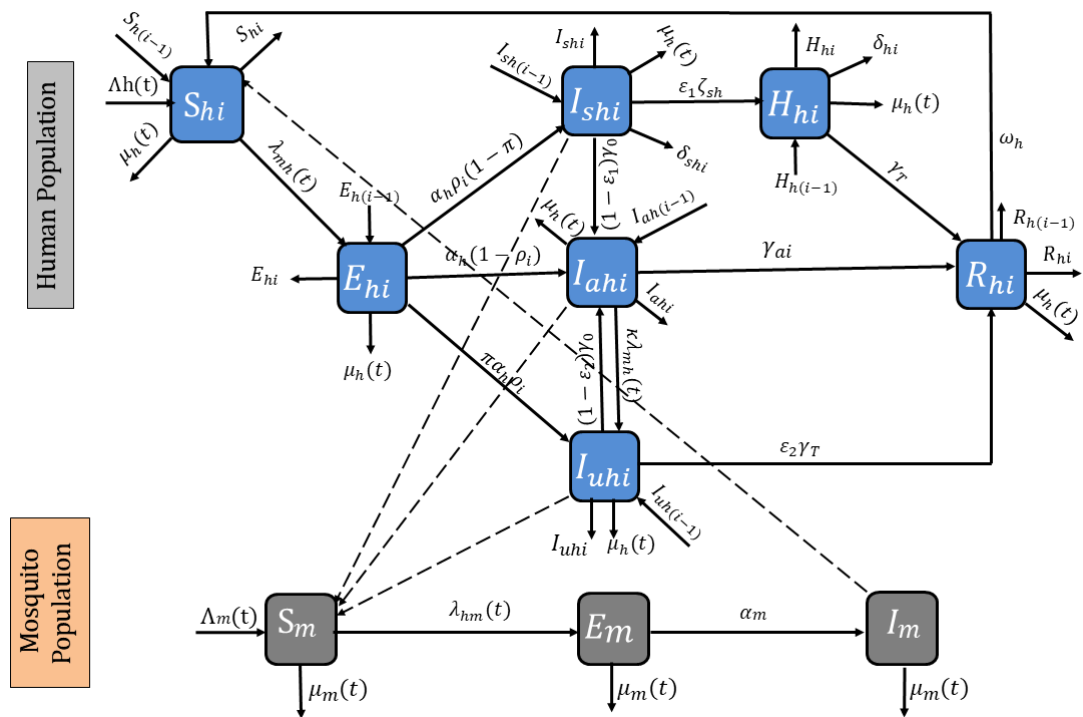
LABEF participated in the support mission for the preparation of the *Carbon Emissions Reduction Project - SCALE-Benin Project*, held from April 15 to 17, 2025, in Cotonou. Supported by the World Bank, this mission focused on refining carbon accounting methodologies for the AFOLU sector (Agriculture, Forestry, and Other Land Use). The laboratory contributed technical expertise to analyze emission factors and activity data, helping to identify key data gaps and establish robust reference levels for the upcoming SCALE-Benin carbon emission reduction initiative.

5.7. Workshop on the inclusion of small-scale rural women farmers in the teaching of local ecological solutions for climate change adaptation in Sub Saharan Africa

On 28–29 June 2025, the laboratory contributed to a two-day training workshop in Malanville, northern Benin, aimed at strengthening the inclusion of small-scale rural women farmers in climate change adaptation. The workshop brought together 62 participants, including 54 women, as well as local authorities and representatives of partner NGOs. Through simple and participatory activities such as group discussions, role-playing, brainstorming and the climate mural, participants improved their understanding of climate change, gender equality and practical adaptation options. They also identified and ranked locally relevant strategies, including changes in farming practices, conservation agriculture, solar-powered drip irrigation and water harvesting. Particular attention was given to women's access to land, climate information, finance, capacity building and farmers' organizations. The training

encouraged participants to recognize rural women as important agents of change and to apply the knowledge gained to improve the resilience and sustainability of their farming activities under increasingly challenging climatic conditions locally. This was done in the framework of the BES project led by Dr Bruno LOKONON,

Inclusion Practices	Prioritization degree			Prioritization coefficient		
	Women	NGOs	Local authorities	Women	NGOs	Local authorities
Incremental Learning				8	6	6
Awareness Campaigns to educate Women Farmers				7	7	8
Capacity-Building				7	8	6
Participating in decision-making bodies				5	5	5
Access to Land				8	7	7
Membership in Organisations				8	8	8
Access to Climate Finance				7	7	8
	Prioritization degree			Prioritization coefficient		
	Women	NGOs	Local authorities	Women	NGOs	Local authorities
Climate Information Access				7	7	8
Participating in Research and Climate Change Discourse				8	7	7
Inclusion in taking of Family Decision				6	6	7
Powerful Agents of change				6	8	6
Woman Development				6	8	8
Monitoring and Evaluation				6	6	8



Flowchart of an age-structured mathematical model to assess the combined effects of vaccine and non-vaccine interventions on malaria transmission and burden developed by Glèlè Kakaï & Djomatin (see <https://doi.org/10.1016/j.idm.2025.10.007>). © LABEF

APPENDIX 1.

Scientific activities in 2025

A1.1. Defended theses in 2025

Name	Sex	Research topic	Research field
DOGBO Sèdoami Flora	F	Peri-Urban Agroforestry Systems: A Pathway to Climate Resilience, Socio-Economic Sustainability, and Biodiversity Conservation in Benin (West Africa)	Climate change and biodiversity
Am Leul	M	Mathematical Modelling and Simulation of Cholera Transmission Dynamics," presents a comprehensive study of cholera epidemiology through various mathematical frameworks	Biometry
ADEOTI Olaiya Mathilde	M	Bayesian Nonlinear Modeling of Correlated Epidemic Data Using Flexible Distributions: A Case Study of COVID-19 Dynamics	Biometry
DETE Clarisse	F	Relative performance of model selection criteria based on Kullback's symmetric divergence in survival analysis of genetic data	Biometry
MONTCHO Yvette	F	Socio-Ecological Modeling of COVID-19 dynamics in Africa	Biometry
AKIN Yaï Yanik	M	Climate, Disturbance and Population Dynamics of a Tropical Fuelwood Tree	Biometry
KAKPO Angeline Reine	F	Uses, fertilising potential and conservation strategies of key agroforestry species in Benin	Natural resources Management
AKODEKOU David	M	Optimizing Agroecosystem Resilience and Sustainability of Inland Valleys to Climate Change in West Africa: Benin Case	Climate change and Agriculture

Dr. DOGBO Sèdoami Flora



Peri-Urban Agroforestry Systems: A Pathway to Climate Resilience, Socio-Economic Sustainability, and Biodiversity Conservation in Benin (West Africa)

The research examined the role of peri-urban agroforestry systems in addressing some of the most pressing challenges facing rapidly urbanizing landscapes in Benin. As cities expand, agricultural lands located at the urban fringe are increasingly exposed to land-use conversion, ecological degradation, and climate-related stress. Within this changing context, peri-urban agroforestry systems represent an important land-use option, as they combine tree-based components with agricultural activities while supporting both ecosystem functions and local livelihoods. The study was conducted across six peri-urban areas of Benin, namely Cotonou, Abomey, Savalou, Parakou, Natitingou, and Kandi, which together capture the country's main climatic zones: Guinean, Sudano-Guinean, and Sudanian. Using field inventories, socio-economic surveys, and spatial modeling, the research adopted an interdisciplinary approach to understand how these systems are structured, what drives their variation, how much carbon they store, and how they may contribute to biodiversity conservation under current and future climate conditions. Data were collected from 323 peri-urban agroforestry plots, each measuring 50 m × 50 m,

alongside interviews with farmers to document socio-economic conditions and management decisions. A first major contribution of the thesis was the characterization of peri-urban agroforestry systems based on woody vegetation attributes. The results revealed clear differences across climatic zones, with wetter zones, especially the Guinean and Sudano-Guinean zones, showing higher tree species richness and diversity. These findings indicate that ecological context strongly shapes the composition and structure of peri-urban agroforestry systems in Benin. At the same time, the study showed that these systems are not determined by biophysical factors alone. Socio-economic analyses demonstrated that farm size, farming experience, residential status, and willingness to plant trees significantly influenced tree density and species richness. This highlights the importance of farmers' decisions, tenure conditions, and management intentions in shaping vegetation outcomes. The thesis also assessed the climate change mitigation potential of these systems through above-ground carbon stock estimation. Among the different agroforestry types, home gardens displayed the highest carbon storage, particularly in the Guinean zone, where values reached about 44.85 Mg C ha⁻¹. In comparison, parklands and plantation agroforestry systems generally stored less carbon and showed greater variability across zones. Beyond comparing system types, the study further explored the mechanisms underlying carbon storage. Functional richness emerged as the strongest and most consistent predictor of above-ground carbon, with positive effects ranging from $\beta = 0.15$ in home gardens to $\beta = 0.33$ in plantation systems and $\beta = 0.31$ in parklands. The analysis also showed that climatic moisture and soil organic carbon contributed indirectly to carbon storage through their influence on vegetation attributes. A final component of the research focused on the future of key multipurpose tree species under climate change. The modeling results

projected a decline in suitable habitats for 67% of the studied species, minor changes for 8%, and increases for 25%. Importantly, Savalou and Abomey emerged as priority biodiversity hotspots under both current and future climatic conditions. This finding underscores the strategic importance of peri-urban areas, not only as spaces under pressure from urbanization, but also as zones that can support biodiversity conservation and long-term climate adaptation efforts. Overall, this thesis demonstrates that peri-urban agroforestry systems in Benin are multifunctional landscapes with strong potential to support climate resilience, carbon sequestration, biodiversity conservation, and livelihood sustainability. By combining ecological analysis, socio-economic assessment, and predictive modeling, the research provides evidence that can inform land-use planning, conservation strategies, and policies promoting sustainable urban expansion in West Africa.

Dr. Am Leul



Mathematical Modelling and Simulation of Cholera Transmission Dynamics," presents a comprehensive study of cholera epidemiology through various mathematical frameworks

The following summary covers the core research and findings detailed in each chapter. The first chapter provides a systematic and critical review of 476 peer-

reviewed articles published between 2012 and 2022. The review identifies that most cholera research is centered in Asia (40%) and Africa (32%). The study categorizes prevalent modeling techniques into three primary groups: compartmental models (52%), statistical models such as time series and regression (21%), and spatial models (9%). A significant finding is the scarcity of research incorporating fly vectors (houseflies) as a transmission pathway, appearing in only a small fraction of studies. Furthermore, vaccination was the most common control measure discussed, featured in 58% of the literature.

The second chapter introduces a deterministic mathematical model using ordinary differential equations to fill the gap identified in Chapter one. This model explicitly incorporates: Stratified Infection: Dividing human hosts into symptomatic and asymptomatic classes; Vector Dynamics: Including an "exposed" compartment for the fly vector population. The analysis proves that the disease-free equilibrium is locally stable when the basic reproduction number (R_0) is less than one. Simulations suggest that reducing exposure to contaminated water and limiting the contribution of infected vectors to the environment are the most effective control strategies. The third chapter extends the deterministic framework into a stochastic CTMC model to account for the inherent randomness in disease transmission. Stochastic Thresholds: Computed using a multitype branching process to determine the probability of extinction versus an outbreak; Sensitivity Analysis: Utilizing Latin Hypercube Sampling (LHS) and Partial Rank Correlation Coefficient (PRCC), the study identifies the natural death rate of vectors (μ_v) as the most sensitive parameter for controlling outbreaks. Numerical simulations indicate that while the stochastic model captures discrete infection states and individual variations, its solutions remain relatively close to the deterministic trends. Chapter 4 investigates the impact of Oral Cholera

Vaccines (OCVs) within a non-linear deterministic model that accounts for seasonality and stratified risk levels. Stratification: The population is divided based on exposure levels (high-risk vs. low-risk); Reproduction Numbers: The study finds R_0 values of 3.35 for the highly exposed group and 2.6 for the less exposed group. Threshold for Control: Findings indicate that to halt transmission, at least 70% of the most exposed population and 62% of the less exposed population must be vaccinated. The chapter concludes that tailoring vaccination strategies to demographic and social risk stratifications significantly improves public health outcomes compared to uniform distribution.

Dr. ADEOTI Olaiya Mathilde



Bayesian Nonlinear Modeling of Correlated Epidemic Data Using Flexible Distributions: A Case Study of COVID-19 Dynamics

Accurate modeling of infectious diseases is essential for understanding and predicting pandemic trajectories and informing effective public health interventions. The complex and heterogeneous nature of epidemic data often poses challenges to standard modeling approaches. This thesis specifically addresses the challenges posed by the complex and heterogeneous

nature of epidemic data by introducing flexible multilevel nonlinear models (SMSN-NLMM and SNP-NLMM) using a Bayesian approach. It aims to evaluate Bayesian nonlinear models for correlated epidemic data using flexible distributions, with a case study of COVID-19 dynamics in West Africa. This would be a significant contribution to global public health policy, particularly, the development agenda of the West Africa countries especially in terms of attainment of the Sustainable Developments Goal 3 (SDG3): Good health and wellbeing. The adopted methodology is based on an interdisciplinary approach combining mathematical modeling, critical analysis, and systematic review. Thus, we first presented a comprehensive systematic and critical review of nonlinear mixed-effects models and related approaches to infectious disease modeling. This first important study provides an overview of the current use of these models and offers a solid foundation for developing guidelines that can improve their implementation in real-world settings. Nonlinear mixed-effects models (NLMMs) have evolved rapidly over the past decade, particularly in the field of infectious disease modeling (IDM), with most publications dating from 2017 to 2021 (83.33%). Through rigorous simulations under various epidemic scenarios and applications to real-world COVID-19 data from seven West African countries, we evaluated Bayesian nonlinear models for correlated epidemic data using flexible distributions. The results demonstrated the significant outperformance of these Bayesian flexible multilevel nonlinear models (SMSN-NLMMs and SNP-NLMMs) over standard nonlinear mixed models (NLMMs) in accurately recovering key epidemic parameters. However, the robustness of models can be compromised by poorly designed estimation methods, particularly due to uncertainties related to prior distributions and initial values. We investigated how different levels of prior informativeness can influence model convergence, parameter estimation, and

computation time in Bayesian flexible multilevel nonlinear model (FLNLM). The results indicate that accurate and informative priors improve prediction performance with minimal impact on computation time. A performance evaluation of two easy Bayesian analysis implementation procedures, specifically for longitudinal infectious disease data, is then conducted to demonstrate the practical utility of this study, especially for practitioners. In conclusion, this research highlights the need to consider the heterogeneity of epidemic data in the analysis and prediction of infectious disease dynamics, as the level of surveillance, preparedness against outbreaks, and pandemic control varies across different geographical resolutions. However, limitations of this study include unaddressed spatial heterogeneity and countrywide covariates explaining divergent trajectories across regions and, exploring our proposition on these lines in future would be an important added value.

Dr. DETE Clarisse



Relative performance of model selection criteria based on Kullback's symmetric divergence in survival analysis of genetic data

Survival analysis is a branch of statistics focusing on time-to-event data and is widely applied in medicine, epidemiology, and agriculture. Various statistical models

have been developed over the years to handle different types of survival data. Examples include the Cox proportional hazards model, accelerated failure time and frailty models, and more complex models such as joint or multi-state models. Selecting an appropriate model is a critical step in survival analysis. Model selection criteria, therefore, play a central role in guiding researchers towards models that balance goodness-of-fit and parsimony. Although traditional criteria such as AIC, $\llbracket$ AIC_c, $\llbracket$ AIC_{sur}, cAIC, $\llbracket$ cAIC_c, BIC, and $\llbracket$ BIC_(n_e) are widely used, their limitations have been noted. Recent research has introduced criteria based on Kullback's symmetric divergence. Survival analysis is a branch of statistics focusing on time-to-event data and is widely applied in medicine, epidemiology, and agriculture. Various statistical models have been developed over the years to handle different types of survival data. Examples include the Cox proportional hazards model, accelerated failure time and frailty models, and more complex models such as joint or multi-state models. Selecting an appropriate model is a critical step in survival analysis. Model selection criteria, therefore, play a central role in guiding researchers towards models that balance goodness of fit and parsimony. Although traditional criteria such as AIC, $\llbracket$ AIC_c, $\llbracket$ AIC_{sur}, cAIC, $\llbracket$ cAIC_c, BIC, and $\llbracket$ BIC_(n_e) are widely used, their limitations have been noted. Recent research has introduced criteria based on Kullback's symmetric divergence. These criteria have been shown to outperform those based on Kullback's directed divergence in both generalized linear and nonlinear models. Despite the increasing use of survival analysis in recent years, none of the KIC criteria have been evaluated. Therefore, this study aimed to assess the performance of KIC family criteria in survival analysis and compare them with traditional criteria. Specifically, the study aimed to review model selection criteria based on Kullback's symmetric and

directed divergences in survival analysis and then assess the performance of model selection criteria based on KSD for the three most used models. A systematic review was conducted using PubMed, Web of Science, and Scopus, identifying 4628 papers. In accordance with PRISMA guidelines, 304 studies were retained. The most commonly used criteria were AIC (94.62%) and $\llbracket \text{AIC} \rrbracket_{-c}$ (3.48%), and none of the selected papers addressed criteria based on Kullback's symmetric divergence. The Cox model (48.95%), parametric proportional hazards models (22.51%), accelerated failure time models (9.95%), and frailty models (8.11%) were the most frequently used. Monte Carlo simulations were then performed under different conditions relating to sample size, censoring rate, error distribution, and frailty distribution. The practical utility of these criteria was also evaluated using real mortality and morbidity calf data. In Cox models, the results revealed that the KIC family criteria performed better in large samples, identifying the best model and selecting one with the best predictive accuracy. AIC tended to select overparameterized models, while BIC favoured more parsimonious models. For accelerated failure time models, the findings suggest that the KIC family criteria outperform the AIC family criteria for moderate to large sample sizes. $\llbracket \text{KIC}_c$ performs better than other criteria for small sample sizes. For small samples, the corrected criteria, such as $\llbracket \text{KIC}_c$, $\llbracket \text{AIC}_c$, and $\llbracket \text{AIC} \rrbracket_{-sur}$, were more reliable. Subsequently, we compared the KIC family of criteria with the cAIC, c $\llbracket \text{AIC}_c$, and $\llbracket \text{BIC}_{(n_e)} \rrbracket_{-ne}$ criteria in semi-parametric shared frailty models. The results showed that the KIC family outperformed the others in identifying the true model for moderate to large sample sizes, except for the c $\llbracket \text{AIC} \rrbracket_{-c}$ criterion. Furthermore, they selected more parsimonious models. The KIC_c criterion, followed by the cAIC_c criterion, identified models with excellent predictive power. The performance of the various criteria

varies depending on the compared model and several factors, including sample size, censoring percentage, error distribution (in the parametric accelerated failure time model), number of clusters, and frailty distribution (in the semi-parametric shared frailty model). Furthermore, the performance of a criterion is determined by how well its penalty term corrects for the negative bias in the goodness-of-fit term. Overall, the KIC family consistently outperformed the AIC family for large sample sizes, selecting more parsimonious and predictive models. Corrected criteria performed better for small samples, while performance depended on factors such as sample size, censoring rate, error distribution, number of clusters, and frailty distribution.

Dr. MONTCHO Yvette



Socio-Ecological Modeling of COVID-19 dynamics in Africa

The COVID-19 pandemic has both highlighted the vulnerabilities and underscored the resilience of African health, social, and economic systems. This thesis adopts an integrative socio-ecological modeling approach to explore the dynamics and impacts of COVID-19 across the continent. Its main objective is to assess how non-pharmaceutical interventions (NPIs), vaccination, seasonal variations, and agricultural disruptions have influenced the trajectory of the

pandemic in African countries. To address these interrelated dimensions, the research uses advanced biostatistical models, climate analyses, and systematic review methodologies. Then in chapter 2 we analyzed the marginal effects of NPIs using an extended, time-dependent SEIR (Susceptible-Exposed-Infectious-Recovered) model in fifteen African countries. The model incorporates stage-specific transmission rates and data on NPI intensity to quantify their effects on pre-symptomatic, mild, and severe cases. The results revealed considerable variation in the effectiveness of NPIs across countries. Gathering-related interventions, such as school closures and bans on public gatherings, were found to be most effective in curbing transmission among pre-symptomatic and mild cases. In contrast, measures focused on private life, such as testing and public information campaigns, were more effective in reducing transmission from severe cases. These findings highlight the importance of tailoring public health strategies to specific national contexts rather than applying uniform measures. Chapter 3 examines the impact of vaccination using a stratified SEIR model that distinguishes between vaccinated and unvaccinated populations. This model evaluates different levels of vaccination coverage, vaccine effectiveness, and NIP adherence. The results indicate that even moderately effective vaccines significantly reduced the reproduction number, particularly when combined with ongoing public health interventions. Countries that achieved high vaccination rates while maintaining NIPs had more favorable epidemiological outcomes. This underscores the fact that, in resource-limited settings, vaccination must be integrated into a broader, multifaceted response strategy. Chapter 4 examines the seasonal dynamics of COVID-19 by classifying African countries into tropical, arid, and temperate climate zones. A time-dependent transmission model

incorporating climate variables was used to assess seasonal fluctuations in COVID-19 incidence. The analysis revealed distinct seasonal patterns, with transmission peaking during cooler and drier periods. The magnitude of these effects varied by climate zone, being more pronounced in temperate and arid regions. These findings suggest that interventions such as vaccination campaigns and NIP intensification should be strategically timed to align with seasonal trends. Chapter 5 presents a systematic analysis of the pandemic's impact on agricultural systems across Africa. Drawing on 87 peer-reviewed studies and policy reports, this chapter identifies direct and indirect disruptions. Direct impacts included labor shortages, disruptions in the input supply chain, and transportation restrictions, while indirect effects included reduced investment, increased food insecurity, and increased vulnerability of smallholder farmers.

Nevertheless, the review also highlights the resilience of agroecological systems supported by localized food networks and informal economies. These findings underscore the urgent need to integrate agricultural and health policy planning in order to build resilience to future pandemics. Overall, this thesis shows that COVID-19 in Africa is best understood as a complex socio-ecological phenomenon. The modeling frameworks and analytical tools presented provide actionable insights for policymakers and health professionals. The findings advocate for context-appropriate public health responses, alignment of health and economic policies, and the development of intersectoral and climate-resilient preparedness strategies. This research offers a comprehensive perspective on epidemic modeling and impact assessment, with implications that extend beyond COVID-19 to other emerging infectious diseases in the region.

Dr. AKIN Yaï Yanik



Climate, Disturbance and Population Dynamics of a Tropical Fuelwood Tree

The thesis investigates how climate interacts with disturbance to shape the population dynamics of tropical trees, using *Prosopis africana*, a key fuelwood species in West Africa, as a model system. First, we developed Bayesian models to assess how climate, disturbance, and community diversity influence early demographic processes, particularly seed pod dispersal and predation. Our results reveal that rodents involved in seed dispersal often act simultaneously as predators, highlighting a dual functional role that directly affects seed fate. Second, we examined the demographic trade-offs underlying the persistence of *P. africana* populations across environmental gradients. Based on data collected from 12 populations over three years, we show that survival–growth trade-offs are stronger in wet and disturbed environments, whereas growth–fecundity trade-offs dominate in moist conditions, regardless of disturbance intensity. Third, we explored how these demographic processes scale up to long-term population dynamics under environmental variability using stochastic Integral Projection Models (IPMs). We found strong interactive effects between climate and disturbance, with drier conditions leading to declining

population growth rates ($\lambda < 1$). Finally, to place these findings in a broader context, we conducted a global meta-analysis using the COMPADRE Plant Matrix Database, encompassing 37 studies. Our results demonstrate that disturbance can either negatively affect populations or trigger compensatory demographic responses, depending on species life form, the plant part harvested, and ecological context. Overall, this thesis highlights how resource allocation strategies are shaped by environmental gradients and emphasizes the context-dependent nature of plant responses to climate and disturbance. These findings underscore the importance of locally adapted management strategies and demonstrate that integrating demographic trade-offs with population dynamics improves predictions of species resilience in heterogeneous environments.

Dr. KAKPO Angeline Reine



Uses, fertilising potential and conservation strategies of key agroforestry species in Benin

Land degradation and declining soil fertility pose serious threats to agricultural production in Benin. In response to these challenges, agroforestry systems based on native tree species represent a strategic option to restore soil fertility, enhance

biodiversity, and support climate adaptation. It is within this context that the present thesis documents the diversity, ecological functions, and conservation potential of these species. To address these issues, a survey of 1,055 farmers, combined with stratified sampling across 54 sites, identified 48 agroforestry species associated with 72 uses, with medicinal applications being the most common. From these findings, three species – *Parkia biglobosa*, *Vitellaria paradoxa*, and *Vitex doniana* – were designated as priorities for their soil-enhancing functions. Their distribution is primarily influenced by farm size, agroecological conditions, and socio-economic characteristics of the farmers. To further explore their fertilising potential, the thesis examines the mineralisation dynamics of leaf biomass from the three species in two soil types, *lixisols* and *ferralsols*. Mixed-effects models reveal significant variations depending on species and pedoclimatic context. In particular, *P. biglobosa* shows maximum nitrogen release on *lixisols* (86.29%), whereas *V. doniana* reaches the highest rate on *ferralsols* (97.92%). These results suggest that species should be matched to soil types to optimise their benefits. Moving to spatial and prospective analyses, five ecological niche modelling algorithms (MaxEnt, RF, SVM, GLM and BRT algorithms, RCP4.5 and RCP8.5 scenarios) were applied. The results indicate current habitat occupancy of 52.10% for *P. biglobosa*, 76.91% for *V. paradoxa*, and 70.22% for *V. doniana*. Looking ahead to 2055, projections suggest a slight contraction of *V. doniana* habitat (-7.36%) and an expansion for the other two species, primarily driven by potential evapotranspiration, cation exchange capacity, and isothermality. Finally, germination trials on *P. biglobosa* were conducted to propose concrete conservation strategies. The highest germination rate (13.25%) was achieved using a substrate composed of 75% potting soil and 25% bokashi compost. After germination, growth performance

improved markedly with moderate use of mineral fertilisers, demonstrating the importance of integrated approaches combining traditional practices with agroecological innovations. Overall, this thesis highlights the crucial role of native tree species in the sustainability of agricultural systems in Benin. It therefore provides practical guidance for restoring soil fertility, conserving biodiversity, and supporting climate change adaptation, while recognising and valuing the knowledge and practices of rural communities.

Dr. AKODEKOU David



Optimizing Agroecosystem Resilience and Sustainability of Inland Valleys to Climate Change in West Africa: Benin Case

The thesis investigates how water management approaches, climate variability, and farmers' adaptive responses jointly shape the ecological functions and agricultural productivity of inland valleys, using Benin's Guinean and Sudano-Guinean agroecosystem zones. Inland valleys are critical wetlands in sub-Saharan Africa, providing a wide range of ecosystem services and serving as a strategic lever for food security. However, their potential remains constrained by inadequate water control and increasing climatic hazards.

First, we assessed the state of ecosystem services delivered under three management approaches (undeveloped valleys, bund valleys, and Smart-Valleys) using a mixed-methods approach that combined quantitative and qualitative data from 298 farmers across 41 inland valleys. Our results reveal that provisioning, regulating, and supporting services in Smart-Valleys are 1.23, 1.20, and 1.06 times higher than in undeveloped valleys, whereas cultural services remain most prevalent in the latter. Smart-Valleys also exhibited fewer threats from drought, flooding, and chemical use, although they were more prone to sedimentation. Socio-economic factors such as gender, age, education, primary activity, and income significantly shaped farmers' perceptions of these services.

Second, we examined the spatiotemporal vulnerability of inland valleys to climatic hazards using biophysical and climate data (1991 to 2021) from 76 inland valleys. We found that 2001, 2002, and 2016 were extreme drought years, whereas 2008, 2009, and 2019 experienced extreme wetness. Drought, affecting 35% of the valleys, predominated in the Sudano-Guinean zone and was best predicted by soil organic carbon, the Standardized Precipitation Evapotranspiration Index (SPEI), and sand content. Wet hazards, observed in 30% of the valleys, prevailed in the Guinean zone and were linked to annual rainfall, sand content, and SPEI.

Third, we explored the mitigation measures adopted by smallholder farmers in response to these hazards. Farmers responded to drought through organic farming (58%), irrigation (47%), and adjusted cropping seasons (85%), while wet and flood hazards triggered changes in cultivation areas (76%), agroforestry and use of straw and fallow (64%), and seasonal adjustments (84%). These adaptation strategies were strongly mediated by market access, extension services, and infrastructure availability,

underscoring the role of institutional support in enabling effective on-farm responses.

Finally, we evaluated the impact of water and nutrient management on rice productivity through two-year field experiments in two contrasting inland valleys (Zoungo and Akété), combining two water management strategies, three fertilizer rates, and three rice varieties. Smart-Valleys consistently maintained higher water levels and soil moisture (1.09 times higher) and a lower Soil Dryness Index (1.56 times lower), accelerating crop growth and increasing grain yield by 43% (5.45 t/ha versus 3.81 t/ha in undeveloped valleys). Nitrogen and phosphorus uptake were 36% higher, while revenue, benefits, and benefit-cost ratios were 1.43, 1.77, and 1.38 times higher, respectively. Combining Smart-Valleys with location-specific fertilization maximized nutrient use efficiency and return on investment.

Overall, this thesis highlights how integrated water and land management, precision

fertilization, climate-smart early warning systems, and the inclusion of cultural services in valley design can collectively strengthen the resilience and sustainability of inland-valley agroecosystems. These findings provide actionable pathways for policymakers, extension agents, and smallholder farmers to enhance food security and climate adaptation across resource-limited settings in West Africa.

A1.2. On-going thesis in 2025

N°	Name	Sex	Level	Topic	Field of research
1	YALINKPON Florent	M	2 nd year	Developing a predictive model for cotton yield in Benin using Artificial Intelligence: A strategic approach for adaptive and sustainable agriculture in the context of climate change	Biostatistics and Biometry
2	LALY Judicaël	M	2 nd year	Predictive performance evaluation of machine learning models with multiple outputs for decision-making in agriculture	Biostatistics and Biometry
3	CRINOT Fabrice Désiré Géraud J. C. E.	M	2 nd year	Optimization of Causal Machine Learning Methods for Heterogeneous Treatment Effect Estimation for Agricultural Decision Making	Biostatistics and Biometry
4	DOSSA Hubert	M	2 nd year	Dynamics of Helicoverpa armigera and Bacterial Blight Disease: Economic Impacts on Cotton Production in Benin	Biostatistics and Biometry
5	ACHIKPA Yabi Akinro Olivier	M	2 nd year	Mathematical modeling of tuberculosis transmission in the presence-absence of vaccination, and treatment.	Biostatistics and Biometry
6	DUKUNDANE Didier	M	2 nd year	Mathematical and Numerical Modeling of COVID-19-Induced Respiratory Dynamics Using Coupled Stokes–Biot Equations: Development of Personalized Models from Computed Tomography Scans	Biostatistics and Biometry
7	KENENISA ABDISA KUSE Kenenisa	F	2 nd year	A comparative study of high-accuracy surface modeling and Machine learning with Euclidean distance field techniques: Exploring the influence of sample size, spatial dependence, Skewness, and outliers on predictive performance with Application in soil science	Biostatistics and Biometry
8	BIYAGUI Issifou	M	2 nd year	Fractional-Order Approaches to Pandemic Modeling: Insights from COVID-19 Dynamics	Biostatistics and Biometry

N°	Name	Sex	Level	Topic	Field of research
9	HAKIZIMANA Emmanuel	M	2 nd year	Optimal Control Modeling of African Maize Stalk Borer (<i>Busseola fusca</i>) Dynamics	Biostatistics and Biometry
10	GANDJI Mirabelle	F	2 nd year	Ecology, biology of conservation and domestication of <i>Ricinodendron heudelotii</i> (Bail.) Pierre ex. Heckel in Benin	Natural Resources Management
11	Sonon Bienvenu	M	3 rd year	Application of artificial intelligence in combination with exponential autoregressive to model rainfall onset-cessation for the improvement of agriculture planning in Benin	Biostatistics and Biometry
12	Tinhoun fréjus Stéphane Sèdjro Cossi	M	3 rd year	Understanding the impacts of interventions on COVID-19 dynamics in West Africa: a hybrid bayesian machine learning framework	Biostatistics and Biometry
13	SODE Akoeugnigan Idelphonse	M	3 rd year	Spatial Fusion Framework for the Joint Analysis of Geospatial Data from Multiple Sources: Ecological and Epidemiological Applications	Biostatistics and Biometry
14	ZINZINHEDO Mahoukpégo Luc	M	4 th year	Combined approach of Machine Learning and spatiotemporal models for cassava (<i>Manihot esculenta</i> C.) yield prediction in Benin under pathogen infestation conditions.	Biostatistics and Biometry
15	GUEDEZOUME Behanzin Marthe Paulette	F	4 th year	Using machine learning techniques to predict soil fertility in Benin	Biostatistics and Biometry
16	TRAORE Kassifou	M	4 th year	A mathematical model for the analysis of malaria incidence and mortality in sub-Saharan Africa: Accounting for population opinion of modern and traditional treatments and prevention methods.	Biostatistics and Biometry
17	ODOUNFA Mireille Gloria F.	F	4 th year	Using deep learning techniques for early detection of chili (<i>Capsicum</i> spp, Tailor and Francis) diseases under constraints of limited sample image, climate variations, and pests.	Biostatistics and Biometry

N°	Name	Sex	Level	Topic	Field of research
18	Dereje Gebeyehu Ababu	M	4 th year	Cointegration of Markets and Their Impact on Income and Productivity of Cereal Crops Producing Households: The Case of Ethiopia	Biostatistics and Biometry
19	BEH MBA Romuald	M	4 th year	Empirical performance of Generalized linear mixed model for point-referenced spatial data with Application to epidemiological data: Disease Mapping	Biostatistics and Biometry
20	ANTENEH Leul Mekonnen	M	4 th year	Modeling of Cholera Epidemics in Ethiopia	Biostatistics and Biometry
20	AGBANGBA Codjo Emile	M	5 th year	Experimental designs and data analysis with linear model in the presence of spatial autocorrelation with applications in soil sciences	Biostatistics and Biometry
21	OROUNLA Bissilimou Rachidatou	F	5 th year	Interplay between personal characteristics, Socio-economic determinants, environmental changes and diseases through Causal Modeling and Structural Equation Modeling	Biostatistics and Biometry
22	TABOE Hemaho Beaugard	M	6 th year	Mathematical meta-population models of emerging and re-emerging communicable diseases' dynamic patterns in developing countries: Application to COVID-19 pandemic and Lassa Fever virus outbreak in West Africa.	Biostatistics and Biometry
23	BOUROBOU Judie Armel	M	6 th year	Inhomogeneous Poisson Process and its extensions for species distribution analysis: Accounting for sampling bias, imperfect detection, non-linear effect and spatial dependence.	Biostatistics and Biometry
24	DAH-DOVONON Virgile-Marx	M	6 th year	Evaluation des stratégies innovantes d'adaptation et apport de l'information climatique dans la Gestion des risques climatiques dans les exploitations agricoles au Bénin	Climate change and agriculture

A1.3. Completed Master in 2025

N°	Name	Sex	Topic	Supervisor(s)	Field of research
1	Nadège AGANDAN	F	Competing risks models, simulations, and applications to the treatment of HIV/AIDS	Prof. Dr. Romain L. GLELE KAKAI Dr (MC) Charlemagne GBEMAVO	Biostatistics
2	Renaud HOUINATO	M	Modeling Climatic Impacts on Pastoral Ecosystems: Integrating Statistical Approaches for Productivity, Resilience, and Optimization in Benin	Prof. Dr. Romain L. GLELE KAKAI Dr (MA) Rodrigue IDOHOU	Biostatistics
3	Yvan GRIRITEKA	M	Enhancing forage yield prediction in Benin using NDVI and Ensemble Machine Learning Approaches	Prof. Dr. Romain L. GLELE KAKAI Dr (MA) Valère SALAKO	Biostatistics
4	Théodora Florice AFFANOU	F	Empirical Performance of K-means, DBSCAN, and Deep Clustering for Segmenting: a case study on Rice Consumers	Prof. Dr. Romain L. GLELE KAKAI Dr (MA) Valère SALAKO	Biostatistics
5	Menalyn Lesly HOUNDOLO	F	Comparative study of High Accuracy Surface Modeling (HASM) and Bayesian Maximum Entropy (BME) under varying data structures	Prof. Dr. Romain L. GLELE KAKAI Dr (MC) Emile AGBANGBA	Biostatistics
6	Ibrahim MOUSSA CHAIBOU	M	Indicateurs de restauration des terres du plateau de kouré, habitat de la girafe au Niger	Prof. Dr. Romain L. GLELE KAKAI Dr (MC) Emile AGBANGBA	Natural Resources Management
7	Ebénézer HOUNDJINO	M	Restauration écologique des mangroves en Afrique de l'ouest à l'aide d'actions de réhabilitation et de reboisement	Prof. Dr. Romain L. GLELE KAKAI Prof. Claudia M. HERNÁNDEZ	Natural Resources Management

N°	Name	Sex	Topic	Supervisor(s)	Field of research
8	Consolas HODONOU	F	Optimizing Cropping Calendars for Major Food Crops in Benin Using Deep Learning-Based Weather Forecasting	Prof. Dr. Ir. Romain L. Glèlè Kakai Dr (MC). Ir. Maurice HOUANSOU	Biostatistics
9	Didier DUKUNDANE	M	Modeling the association of rainfall and temperature with malaria incidence in Adamawa State, Nigeria	Prof. BAKARE Emmanuel Afolabi Dr. Kolawolé Valère SALAKO	Biostatistics
10	Diane ZANVO	F	Modelling the impact of vaccination on cholera transmission dynamics under stratified populations and seasonality.	Prof. Romain L. GLELE KAKAI Dr Ir. Kolawolé Valère SALAKO	Biostatistics
11	Walter LOKOSSOU	M	Application of Nonlinear Regression Models and Multilayer Perceptron Neural Networks for Maize Yield Prediction in Benin	Prof. Dr. Romain L. GLELE KAKAI Dr. Castro G. HOUNMENOU	Biostatistics
12	Ludosky DJOMATIN	M	An Age-Structured Mathematical Model to Assess the Combined Effects of Vaccine and non-Vaccine Interventions on Malaria Transmission, Burden and Severity	Prof Romain GLELE KAKAI	Biostatistics
13	G. A. Maryline SINLETE	F	Modelling the impact of climate on cholera disease transmission dynamics in Africa: a spatial regression approach	Pr. Romain GLELE KAKAI Dr. Kolawole Valere SALAKO	Biostatistics
14	Roy ABALLO	M	Efficient Deep Learning in Resource-Constrained Environments: A Study of Data Augmentation for Lightweight Models	Prof. Dr. Ir. Romain GLELE KAKAI Dr. Ir. Emile Codjo AGBANGBA	Biostatistics

N°	Name	Sex	Topic	Supervisor(s)	Field of research
15	Charbel Canisius AIYA	M	Spatio-temporal modeling of face mask use during COVID-19 in West Africa community	Prof. Romain Glèlè kakai Dr. Télé Jonas DOUMATE	Biostatistics
16	Surya Nondomè Ludmila AHAMIDE	F	Direct and Indirect Effects of Determinants of Malaria Dynamics in West Africa: A Spatial Bayesian Structural Equation Modelling Approach	Pr. Romain GLELE KAKAI Dr. Kolawole Valere SALAKO	Biostatistics
17	Carine Tatiana Sègnimaké MINABA	F	Mediating effects of Non-Vaccine Interventions on Malaria Dynamics: A comparison of Partial Least Squares and Covariance-Based Structural Equation Modeling	Pr. Romain GLELE KAKAI Dr. Kolawole Valere SALAKO	Biostatistics
18	Cabrel Oswald GANGBE	M	Robustness of Machine Learning and Bayesian Maximum Entropy methods in spatial interpolation: Impact of Spatial Dependency, Sample Size and Skewness	Pr. Romain GLELE KAKAI Dr (MC) Emile AGBANGBA	Biostatistics
19	Melkisédek M. VLAVONOU	M	Agent-based modelling of malaria transmission and burden in central Benin in 2023 : Assessing the impact of non-vaccine interventions	Pr. Romain GLELE KAKAI Prof. Barikissou Georgia Damien	Biostatistics
20	Jedida Kasyoka Kimanthi	F	Prevalence and determinants of anaemia in pregnancy in Africa: An umbrella review and updated meta-analysis.	Pr. Romain GLELE KAKAI Dr. Kolawole Valere SALAKO	Biostatistics

N°	Name	Sex	Topic	Supervisor(s)	Field of research
21	Sovègnon Géraud H. NASSOUHOUNDE	M	Variation du stock de carbone des mangroves, et de ses déterminants dans le pôle côtier du site Ramsar 1017	Pr. Achille ASSOGBADJO Dr. Kolawole Valere SALAKO	Natural Resources Management
22	Gbènalè E. Ronel BOSSA	M	Variation du stock de carbone et ses déterminants dans les écosystèmes de mangroves du Lac Ahémé du site RAMSAR 1017	Pr. Achille ASSOGBADJO Dr. Kolawole Valere SALAKO	Natural Resources Management
23	Billy Lionnel Kévin OGOUBIYI AKILOTAN	M	Services écosystémiques et structure de la population de <i>Ricinodendron heudelotii</i> (Baill.) Pierre ex Heckel dans la zone Soudano-Guinéenne du Bénin	Pr. Achille ASSOGBADJO Dr. Kolawole Valere SALAKO	Natural Resources Management
24	Kossi MENSAH	M	Ethnobotanique et structure des populations de <i>Ricinodendron heudelotii</i> (baill.) Pierre ex Heckel au Togo (Afrique de l'Ouest)	Pr. Achille ASSOGBADJO Dr. Kolawole Valere SALAKO	Natural Resources Management
25	Lydie Joëlla BONOU	F	Services écosystémiques et structure des populations de <i>Ricinodendron heudelotii</i> (Baill.) Pierre ex Heckel dans la zone humide (Guinéo-Congolaise) du Bénin	Pr. Achille ASSOGBADJO Dr. Kolawole Valere SALAKO	Natural Resources Management
26	Christelle DEMENOU	F	Evaluation de la valeur économique totale des services écosystémiques des mangroves et de leurs déterminants dans le pôle Lac Ahémé du site Ramsar 1017	Pr. Romain GLELE KAKAI Dr (MA) Ademonla D. ARINLOYE	Natural Resources Management

A1.4. Scientific papers published in peer-review journals IF in 2025

N°	Discipline	Authors' Names	Title of the article	Journals	IF
1	Climate change and biodiversity	Agounde G., Salako K.V., Idohou R. A. F., Sode A. I., Mensah S., Dimobe K., Assogbadjo A.E., Glèlè Kakaï R.	Climate change may shift the diet of the African savanna elephant: Preliminary results for 14 food tree and shrub species in the WAPOK transboundary ecosystem, West-Africa	Global Ecology and Conservation	3.4
2	Biometry	Dete C.H., Lokonon B.E., Gneyou K.E., Senou M., Glèlè Kakaï R.	Relative Performance of Model Selection Criteria for Cox Proportional Hazards Regression Based on Kullback's Symmetric Divergence	Journal of Probability and Statistics	1.3
3	Climate change and biodiversity	Dogbo S.F., Salako K.V., Agounde G., Dimobe K., Adiko A.E.G., Gebauer J., Adou Yao C.Y., Glèlè Kakaï R.	Potential impacts of future climate on twelve key multipurpose tree species in Benin: Insights from species distribution modeling for biodiversity conservation	Trees, Forests and People	2.9
4	Biometry	Gongnet E.E., Vihotogbé R., Agbangba E., Affossogbé T., Djondang K., Glèlè Kakaï R.	Impact of Box-Cox Transformation Technique on the Bayesian Maximum Entropy (BME) Prediction Accuracy	JP Journal of Biostatistics	0.1
5	Forestry	Kolawole M.A., Salako K.V., Akakpo A.D.M., Noulèkoun F., Assogbadjo A.E., Glèlè Kakaï R., Dimobe K.	Provenance and Tree-to-Tree Differences in Germination Performance of <i>Balanites aegyptiaca</i> (L.) Delile: Insights for Domestication and Selection	Heliyon	3.6
6	Forestry	Kochoni B.I., Salako K.V., Danquah J.A., Sinsin C.B.L., Mensah S., Glèlè Kakaï R.	Contribution of the Ramsar Convention to the Conservation of West-African Mangroves: A Case Study in Benin	Wetlands Ecology and Management	1.6
7	Forestry	Lykke A.M., Rømer N., Gonzalez P., Glèlè Kakaï R., Rabiou H.,	Tree populations show low regeneration of valued species in West Africa	Biological Conservation	4.4

N°	Discipline	Authors' Names	Title of the article	Journals	IF
		Amegnaglo K.B., Ganaba S., Sambou B., Niang F., Herault B., Tang Guuroh R., Ouobam P., Yaméogo J.T., Traoré L., Sinsin B., Amahowe O.I., Baya S.S., Houehanou T.D., Houessou L.G., Gouwakinnou G.N., Yetein M.H., Tanko B., Ouédraogo A., Ouédraogo I., Taitar P., Amanis B.H.K., Coulibaly B., Kouyaté A.M., van Damme P., Vanhove W., Mahaman A., Bonache C., Sambou S., Soumana I., Amanz A., Maârouhia I.M., Barfod A.S.			
8	Ecology	Manda L., Idohou R., Agoyi E., Agbahoungba S., Salako K.V., Agbangla C., Adomou A.C., Assogbadjo A.E.	Progress of in situ conservation and use of crop wild relatives for food security in a changing climate: a case of the underutilised <i>Vigna</i> spp	Frontiers in Sustainability	2.9
9	Biometry	Montcho Y., Amoussouvi K.T., Atchadé M.N., Salako K.V., Hounkonnou M.N., Wolkewitz M., Glèlè Kakaï R.	Assessing the potential seasonality of COVID-19 dynamic in Africa: a mathematical modeling study	Modeling Earth Systems and Environment	2.9

N°	Discipline	Authors' Names	Title of the article	Journals	IF
10	Ecology	Noulèkoun F., Mensah S., Kim H., Houndonougbo J.S.H., Mensah M., Lee W.K., Son Y., Khamzina A.	Contrasting ecological mechanisms mediate the impact of land conversion on ecosystem multifunctionality	Functional Ecology	5.1
11	Climate change and agriculture	Tahi S.P.G., Salako K.V., Houndji V.R., Glèlè Kakaï R.	Effects of weather scenarios and fertilizer on maize growth and yield: Insights from a greenhouse experiment	PLOS ONE	2.6
12	Forestry	Tiétiambou F.R.S., Dimobe K., Salako K.V., Lankoandé B., Ouédraogo A.	Seeds of Sustainability: Unveiling the Population Dynamics of <i>Carapa procera</i> , <i>Lophira lanceolata</i> , and <i>Pentadesma butyracea</i> for Adaptive Oilseed Value Chains	African Journal of Ecology	1.1
13	Biometry	Adéoti O.M., Diop A., Hounkonnou M.N., Glèlè Kakaï R.	Bayesian flexible multilevel nonlinear models in infectious disease modeling using non-informative priors	Biostatistics&Epidemiology	1.3
14	Ecology	Agbohessou M., Mensah S., Salako K.V., Ngom A., Agounde G., Noba K., Glèlè Kakaï R., Assogbadjo A.E.	Variation in the potential impacts of climate change on the baobab in Sub-Saharan Africa: A continental analysis across major climate zones	Global Ecology and Conservation	3.4
15	Ecology	Agraz Hernandez C.M., Houndjinou E., Reyes Castellanos J.E., Chan Keb C.A., Osti Saénz J., Chavez Barrera J.C., Etienne J., Glèlè Kakaï R., Puschendorf R.	Hydrological repair and invasive grass removal restore <i>Rhizophora racemosa</i> mangrove communities in West Africa	Restoration Ecology	2.7

N°	Discipline	Authors' Names	Title of the article	Journals	IF
16	Ecology	Akin Y.Y., Gaoue O.G.	Phylogenetic diversity and seed pod traits altered seed pod fate in disturbed environments	Global Ecology and Conservation	3.4
17	Environmental Sciences	Akoton T.P., Hountondji Y.C., Sourou B.N., Tcheton S., Wedjangnon A.A., Houèthégon T., Sogbossi S.E., Salako K.V., Ouinsavi C.	The influence of household socioeconomic profiles on the use of mangrove resources along the Benin coastline	Frontiers in Ocean Sustainability	2.3
18	Biometry	Anteneh L.M., Glèlè Kakaï R., Zanvo S.D., Traore K.	Modelling the impact of vaccination on cholera transmission dynamics under stratified populations and seasonality	Infectious Disease Modelling	2.5
19	Ethnobotany	Daï E.H., Idohou R., Toyi S.S.M., Houndonougbo J.S.H., Azihou F.A., Ouédraogo A., Hotes S., Assogbadjo A.E.	Utilitarian diversity and options for the sustainable use of the bush banana <i>Uvaria chamae</i> P. Beauv. in Benin (West Africa)	Journal of Ethnobiology and Ethnomedicine	1.3
20	Environmental Sciences	Dotonhoué C.F.G., Agounde G., Wedjangnon A.A., Ouinsavi C.	Modelling current and future suitable cultivation areas of cashew trees in Benin (West Africa) based on the major parasite and its parasitoid distribution under global climate warming	Remote Sensing Applications: Society and Environment	4.1
21	Environmental Sciences	Gnansounou S.C., Akodekou A.D., Salako K.V., Houndjinou E., Apithy E., Glèlè Kakaï R.	From the table to the mill: a socio-cultural valuation of the dynamics in mangrove oyster exploitation in Togo Republic using qualitative methods	Maritime Studies	2.3

N°	Discipline	Authors' Names	Title of the article	Journals	IF
22	Environmental Sciences	Kpoviwanou Houndjo M.R.J., Ouinsavi C., Alaye E.A., Wedjangnon A.A.	Gendered trends and barriers in agroforestry adoption in Benin (West Africa)	Discover Sustainability	3.0
23	Ecology	Jucker T., Fischer F.J., Chave J., Coomes D.A., Caspersen J., Ali A., Loubota Panzou G.J., Feldpausch T.R., Falster D., Usoltsev V.A., Jackson T.D., Adu-Bredu S., Alves L.F., Aminpour M., Angoboy Ilondea B., Anten N.P.R., Antin C., Askari Y., Ayyappan N., Banin L.F., Barbier N., Battles J.J., Beeckman H., Bocko Y.E., Bond-Lamberty B., Bongers F., Bowers S., van Breugel M., Chantrain A., Chaudhary R., Dai J., Dalponte M., Dimobe K., Domec J.- C., Doucet J.-L., Dupuy Rada J.M., Duursma R.A., Enríquez M., van Ewijk K.Y., Farfán-Rios W., Fayolle A., Ferretti M., Forni E., Forrester D.I., Gilani H., Godlee J.L., Haeni M., Hall J.S., He J.-K., Hemp A., Hernández-Stefanoni J.L., Higgins	The global spectrum of tree crown architecture	Nature Communications	15.7

Nº	Discipline	Authors' Names	Title of the article	Journals	IF
		S.I., Holdaway R.J., Hussain K., Hutley L.B., Ichie T., Iida Y., Jiang H.- S., Joshi P.R., Kaboli H., Kazempour Larsary M., Kenzo T., Kloeppel B.D., Kohyama T.S., Kunwar S., Kuyah S., Kvasnica J., Lin S., Lines E.R., Liu H., Lorimer C., Loumeto J.-J., Malhi Y., Marshall P.L., Mattsson E., Matula R., Meave J.A., Mensah S., Mi X., Momo S.T., Moncrieff G.R., Mora F., Muñoz R., Nissanka S.P., Nur Hajar Z.S., O'Hara K.L., Pearce S., Pelissier R., Peri P.L., Ploton P., Poorter L., Pour M.J., Pourbabaei H., Ribeiro S.C., Ryan C., Sanaei A., Sanger J., Schlund M., Sellan G., Shenkin A., Sonké B., Sterck F.J., Svátek M., Takagi K., Trugman A.T., Vadeboncoeur M.A., Valipour A., Vanderwel M.C., Vovides A.G., Waldner P., Wang W., Wang L.-Q., Wirth C., Woods M., Xiang W., de			

N°	Discipline	Authors' Names	Title of the article	Journals	IF
		Aquino Ximenes F., Xu Y., Yamada T., Zavala M.A., Zimmermann N.E.			
24	Ecology	Kochoni B.I., Salako K.V., Dimobe K., Agounde G., Zanvo S.D., Danquah J.A., Glèlè Kakaï R.	Impact of Anthropogenic Activities and Climate Change on Carbon Stock in a West-African Mangrove	Wetlands	2.0
25	Forestry	Gbedomon R.C., Salako K.V., Delorme D., Schlaepfer M.A.	Quantifying the Diversity of Normative Positions in Conservation Sciences	Conservation	1.9
26	Forestry	Gnansounou S.C., Salako K.V., Bonou A., Gbedomon R.C., Denon L., Assogbadjo A.E., Glèlè Kakaï R.	Mat making from <i>Cyperus articulatus</i> in mangrove areas: a value chain analysis and economic insights in Benin (West Africa)	Trees, Forests and People	2.9
27	Forestry	Ofori S.A., Hugé J., Gnansounou S.C., Ximenes A.C., Asante F., Bagbohouna M.k., Comte A., Longépée E., Lang'at K.S., Bandeira S.O., Omollo D., Onyena A.P., Sam K., Hamza A.J., Zeggaf Tahiri A., Daf D.S., Goudiaby K.D., Olatunji E.T., Golléty C., Padonou E.A., Dahdouh-Guebas F.	Leveraging mangroves to advance climate action in Africa: Zooming in on Nationally Determined Contributions (NDCs)	Journal of Environmental Management	8.4
28	Ecology	Sabo P., Tiétiambou F.R.S., Guindé H.T., Salako K.V., Johnson S., DeCarlo A., Mensah S., Glèlè Kakaï R., Ouédraogo A.	Socio-cultural Factors Affecting Traditional Knowledge and the Cultural Significance of the Aromatic and Medicinal Plant, <i>Boswellia dalzielii</i> Hutch., in Burkina Faso	Human Ecology	1.7

N°	Discipline	Authors' Names	Title of the article	Journals	IF
29	Forestry	Adjacou D.M., Idohou R., Yaoitcha A.S., Ayena J.K.I., Houehanou T.D., Gouwakinnou G.N	Integrating phenotypic and genetic diversity, and species distribution modeling to set long-term conservation strategies for the endangered <i>Afzelia africana</i> in Benin (West Africa)	Trees, Forests and People	2.9
30	Agronomy	Akodekou A.D., Dossou-Yovo E.R., Salako K.V., Gnansounou S.C., Diarra S.T., Nehren U., Glèlè Kakaï R.	Drought and flood hazards in inland valleys of Benin: severities, adaptation strategies and associated factors across the Sudano-Guinean and Guinean zones	International Journal of Disaster Risk Reduction	4.5
31	Agroforestry	Assalé A.A.Y., Hounsou-Dindin G., Konan G.D., Donou Hounsodé T.M., Salako K.V., Barima Y.S.S., Glèlè Kakaï R.	Cocoa agroforestry and biodiversity: identification of priority species for sustainable management in Côte d'Ivoire	Agroforestry Systems	2.2
32	Forestry	Assogbadjo C.S., Avocèvou-Ayisso C., Wouyou H.G., Idohou R., Agontinglo E.L.T., Bailey M.W., Aiya C.C., Assogbadjo A.E.	Use patterns and distribution of indigenous knowledge on three <i>Momordica</i> species in Benin, West Africa	Journal for Nature Conservation	2.5
33	Forestry	Avakoudjo H.G.G., Vodounnon M.E.J., Idohou R., Coulibaly A., Assogbadjo A.E.	Ensemble modelling reveals spiny monkey orange (<i>Strychnos spinosa</i> Lam.) as a vulnerable wild edible fruit tree in West Africa	Ecology, and Landscapes	3.7
34	Biometry	Beh Mba R., Glèlè Kakaï R.	Bayesian Modeling of Geostatistical Survival Data With Misaligned Covariates: A Simulation-Based Study of Malaria Risk in Gabon	Journal of Probability and Statistics	1.3

N°	Discipline	Authors' Names	Title of the article	Journals	IF
35	Forestry	Biaou S., Sodedji A.F., Salako K.V., Noulèkoun F., Hounwanou G.B., Houehanou T.D., Ouinsavi C., Gouwakinnou G.N.	Variability in <i>Pterocarpus erinaceus</i> Poir. Traits Along an Aridity Gradient Provides Insights Into Its Adaptation to Dry Environmental Conditions	African Journal of Ecology	1.1
36	Forestry	Biaou S., Noulèkoun F., Salako K.V., Houehanou T.D., Ouinsavi C., Gouwakinnou G.N.	A global synthesis of research on plant local adaptation to climate change: plant diversity, methodological approaches and future roadmap	Scientific African	3.3
37	Coastal Zone Management	Gnansounou S.C., Salako K.V., Pellowe K.E., Diallo K., Glèlè Kakaï R., Kestemont P., Henry S.	Synergies between legal frameworks and traditional rules, and their potential for enhancing the social-ecological resilience of mangroves	Ocean & Coastal Management	5.4
38	Forestry	Kpetikou C.G., Agounde G., Dassou G.H., Salako K.V., Tossou G.M., Hedderson T.	Current Knowledge and Research Perspectives on Bryophytes in West Africa	Diversity	2.1
39	Ecology	Mensah S., Sheppard J., Noulèkoun F., Assogbadjo A.E., Salako K.V., Dimobe K., Glèlè Kakaï R., Seifert T.	Legacy effects of fire on tree diversity, structure and aboveground carbon in tropical semi-arid naturally assembled communities	Ecological Informatics	7.3
40	Forestry	Tokannou I.E., Sanogo S., Salako K.V., Hounkpèvi A., Dogbo S.F., Fandohan A.B.	Cultural and socio-economic drivers of conservation and cultivation of the cola nut tree	Agroforestry Systems	2.2

A1.5. Scientific papers published in peer-review indexed journals WIF in 2025

N°	Disciplines	Authors' Names	Title of the article	Journals
1	Ecology	Konda B., Dimobe K., Salako K.V., Dembélé J.B., Boussim I.J.	Morphological Variability of <i>Pterocarpus erinaceus</i> Poir. Along a Climate Gradient in Burkina Faso, West Africa: Implications for Conservation and Domestication	Genetic Resources and Crop Evolution
2	Forestry	Lokossou R.S., Akponikpè I.P.B., Matilo A.O., Davakan R., Glèlè Kakaï R., Ganglo J.C., Mensah G.A.	Tropical Rainforest Agroecosystems Sustainability by Efficient Soil Fertility and Water Management: Case of "Trois Rivières" Forest Reserves in Benin	Next Research
3	Ecology	Salako K.V., Dassou G.H., Gnansounou S.C., Zanvo M.G.S., Akodekou A.D., Glèlè Kakaï R.	Wetlands of Benin (West Africa): Biodiversity, Livelihoods, and Conservation	Wetlands of Tropical and Subtropical Asia and Africa: Biodiversity, Livelihoods and Conservation
4	Ethnobotany	Wouyou H.G., Avocèvou-Ayisso C., Idohou R., Assogbadjo C.S., Houndonougbo J.S.H., Assogbadjo A.E.	Current knowledge and future prospects of African plants providing natural dyes: a systematic review	Discover Plants
5	Forestry	Ahononga F.C., Sonounameto R.C., Akabassi G.C., Gouwakinnou G.N., Biaou S., Biaou S.S.H.	Impacts of land-use change on carbon storage and sequestration in forest ecosystems in Benin	Discover Applied Sciences
6	Forestry	Salako K.V., McGregor S.G., Suárez E.L.	North IUCN Red List of Ecosystems, Mangroves of the Gulf of Guinea -North	EcoEvoRxiv

7	Forestry	Assogbadjo C.S., Avocèvou-Ayisso C., Idohou R., Wouyou H.G., Houndonougbo J.S.H., Hounsou-Dindin G., Assogbadjo, A.E.	A review of <i>Momordica</i> species in Africa (Cucurbitaceae): current knowledge and perspectives for sustainable management	Ethnobotany Research and Applications
8	Forestry	Gandji M.R.M., Salako K.V., Hounsou-Dindin G., Glèlè Kakaï R., Assogbadjo A.E.	Ecosystem services provided by <i>Ricinodendron heudelotii</i> (Baill.) Pierre ex Heckel in Benin: Local perception and associated factors	Environmental Challenges
9	Forestry	Idohou R., Wouyou H.G., Agbangba E., Dossou A.	Utilitarian diversity of <i>Senna occidentalis</i> in Benin, West Africa: Ethnobotanical insights and sustainable management	Ethnobotany Research and Applications
10	Ecology	Kégbé A.M., Idohou R., Dieng B., Agounde G., Egeru A., Noba K., Assogbadjo A.E.	Solanum wild relative species indicate varying ecological resilience to climate change in Benin (West Africa)	Genetic Resources
11	Agroforestry	Kouhouenou V., Hounsou-Dindin G., Teka O., Tchékoté H.	Vulnerability of agrosystems to climate change in the surrounding areas of Pendjari National Park of Benin	Discover Agriculture
12	Machine learning	Odounfa M.G.F., Hounmenou C.G., Salako K.V., Affokpon A., Glèlè Kakaï R.	Deep learning enables precision agriculture for sustainable chili pepper disease detection in Benin	Discover Artificial Intelligence
13	Agronomy	Tognisse I.S., Degila J., Sounouvou M., Sodedji A.F., Salako K.V., Agbahoungba S., Agoyi E., Ahouansou M., Assogbadjo A.E.	Digital Technology and the Crop Calendar for Efficient Agriculture in West Africa	Telecommunications Engineering

A1.6. Scientific papers published in non-indexed peer-review journals in 2025

N°	Disciplines	Authors' Names	Title of the article	Journals
1	Biometry	Adéoti O.M., Diop A., Glèlè Kakaï R.	Bayesian inference and impact of parameter prior specification in flexible multilevel nonlinear models in the context of infectious disease modeling	Mathematical Biosciences and Engineering
2	Agronomy	Kakpo D.A.R., Bankolé E., Sossa E.L., Amadji G.L., Dagbénonbakin D.G., Buri M.M., Glèlè Kakaï R.	Pruning leaf mineralization dynamic of three agroforestry species on two major soil types in Benin	Bulletin de la Recherche Agronomique du Bénin (BRAB)
3	Machine learning	Tinhoun F.S., Doumatè T.J., Glèlè Kakaï R.	Deep learning-based methods for predicting COVID-19: A critical review	African Journal of Applied Statistics

A1.7. Books and book chapters in 2025

N°	Field of research	Authors' Name	Title	References
1	Climate change and agriculture	Akodekou A.D., Dossou-Yovo E.R., Salako K.V., Diarra S.T., Nehren U., Glèlè Kakaï R.	Assessment of Smallholder Farmers' Mitigation Strategies to Climatic Hazards in the Inland Valleys of Central Benin: The Case of Drought and Flood	In: Leal Filho, W., Matandirotya, N., Yayeh Ayal, D., Luetz, J.M., Borsari, B. (eds) Climate Change, Food Security, and Land Management. Springer, Cham. https://doi.org/10.1007/978-3-031-71164-0_73-1

A1.8. Participation to conferences/seminars/workshops in 2025

N°	Title, Place and period of the conference/seminar	Type of Presentation	Attendee
1	Navigating Change in Agro-Pastoral Systems, Benin, September	Training	HAKIZMANA Emmanuel
2	Applied Malaria Modeling Network (AMMnet) Annual Meeting, Senegal (Dakar), June	Oral	BEH MBA Romuald
3	Formation à la gestion des données et à l'analyse statistique destinée aux sites de surveillance sentinelle du paludisme, Libreville (Gabon), February	Oral	BEH MBA Romuald
4	GeoTraining Summer School 2025, Germany, September	Training	DUKUNDANE Didier
5	Tropentag 2025 Conference, Germany, September	Training	DUKUNDANE Didier
6	3rd ICAMMDA International School on Modelling & Analytics, Nigeria, June	Training	DUKUNDANE Didier
7	École Mathématique Africaine 2025, Benin, April	Training	DUKUNDANE Didier
8	Deep learning-based methods for predicting COVID-19 : A critical review, Benin, September	Oral	TINHOUN Fréjus Stéphane Sèdjro Cossi
9	Conférence : Second online Symposium of the African Society for Biomathematics, Online, December	Training	TINHOUN Fréjus Stéphane Sèdjro Cossi
10	Ecole Mathématique Africaine (EMA) : Mathématiques, Science des données et Intelligence Artificielle : Enjeux et défis, Benin, April	Oral	BIYAGUI Issifou
11	Mercredis scientifiques 2025-2026 – Donnez de la Voix à vos Valeurs (DVV) : démarche constructive et consensuelle pour contrer les Actions non Ethiques, Benin, November	Training	BIYAGUI Issifou

12	Scientific Seminars and Conferences – Scientific research for academic excellence : Why is investment in university research a driver of innovation ? Benin, October	Training	BIYAGUI Issifou
13	De la Recherche scientifique pour l'excellence Académique, Benin, October	Training	Inconnu
14	Cohort on Academic Career Planning (Module 3) : An international six (06) weeks online training organized by the DAAD office, Online, October & November	Training	LALY Judicaël
15	Data Science for Research and Institutional Intelligence Workshop : practical Workshop on Data Science for Research and AI, organized by RUFORUM, Online, August	Training	LALY Judicaël
16	Data Management for Research and Institutional Decision Making: practical Workshop on Data Management and Data Analysis Using the R, organized by RUFORUM, Online, July	Training	LALY Judicaël
17	AI-driven based machine learning approach to application of soil data prediction for inclusive and sustainable agricultural transformation in Africa, Algeria, December	Oral	KUSE Kenenisa Abdisa
18	First Virtual International Congress on Computational Biology, Bioinformatics and Artificial Intelligence (1st VIC-CBBAl-25), Algeria, December	Training	KUSE Kenenisa Abdisa
19	Model performance comparison on machine-learning enhanced euclidean distance field-based approach, bayesian maximum entropy, high-accuracy surface modelling, and their hybrids on soil data prediction, Nigeria, February	Oral	KUSE Kenenisa Abdisa

20	International Workshop on Defining Research and Innovation Strategy for Excellency, Nigeria, October	Training	KUSE Kenenisa Abdisa
21	Improving agricultural efficiency with artificial intelligence and Data analytics: an analysis of corn yield prediction, Nigeria, September	Oral	KUSE Kenenisa Abdisa
22	Six-day international conference and workshop on applied mathematical modelling & analytics, Nigeria, February	Training	KUSE Kenenisa Abdisa
23	Séminaire sur « La recherche scientifique au service de l'excellence académique », Benin, October	Training	KUSE Kenenisa Abdisa
24	4th International Conference on Public Health in Africa (CPHIA), Benin, October	Training	KUSE Kenenisa Abdisa
25	Séminaire sur « Le paludisme, morbidité, manifestations symptomatologiques et phytotraitements », Benin, November	Training	KUSE Kenenisa Abdisa
26	Risk Perception and Impacts of Non-conventional Medicine on COVID-19 in West Africa: A Partial Least Square Structural Equation Modelling (PLS-SEM), Benin, September	Oral	Orounla Bissilimou Rachidatou
27	Atelier: Simple and advanced sampling techniques in research (Schisquares), Online, November	Training	Orounla Bissilimou Rachidatou
28	Deep Learning Indaba Conference, Rwanda, August	Training	GUEDEZOUME BEHANZIN Marthe Paulette
29	Women's Leadership and Management Course (WLMC) (AWARD), Kenya, November & December	Training	GUEDEZOUME BEHANZIN Marthe Paulette
30	Tech Solution: Donor-Facing Mobile App, Rwanda, November	Oral	SODE Akoeugnigan Idelphonse

31	Smart Soil Monitoring with Raspberry Pi, Rwanda, November	Oral	SODE Akoeugnigan Idelphonse
32	Intégration des données de présence et d'abondance pour prédire la distribution du baobab africain : un cadre de modélisation bayésienne par fusion de données, Benin, September	Oral	SODE Akoeugnigan Idelphonse
33	Deep Learning Indaba Conference, Benin, August	Training	SODE Akoeugnigan Idelphonse
34	Principle of Data Interpretation and Scientific Communication Workshop, Benn, February	Training	SODE Akoeugnigan Idelphonse
35	Assessing the effectiveness of Seasonal Malaria Chemoprevention on Malaria Burden Among Children Under 5 in Northern Benin: A Statistical Modelling Approach, Senegal, June	Poster	Sonounameto Roland Christel
36	Assessing the effectiveness of Seasonal Malaria Chemoprevention on Malaria Burden Among Children Under 5 in Northern Benin : A Statistical Modelling Approach, Kenya, July	Oral	Sonounameto Roland Christel
37	The NMCP – MamodAfrica Workshop, Benin, October	Training	Sonounameto Roland Christel
38	Deep Learning Indaba 2025, Rwanda, August	Training	ODOUNFA Mireille Gloria Founmilayo
39	Implications éthiques et socio-économiques de l'IA au Bénin, Benin, November	Oral	ODOUNFA Mireille Gloria Founmilayo
40	Assessment of performance of trivariate endogeneous probit model, Benin, January	Oral	CRINOT Fabrice Désiré Géraud J.C.E.

41	Influence of Spatial Autocorrelation, Imperfect Detection, and Sample Size on Predictive Performance of Inhomogeneous point Process Models trained with presence-only data, Benin, July	Oral	BOUROBOU BOUROBOU Judi Armel
42	3 ^{ème} Journée Scientifique de L'Institut de Recherches Technologiques. Thème : Recherche et Innovation au Service du Développement, Libreville (Gabon), July	Training	BOUROBOU BOUROBOU Judi Armel
43	Modeling the spatial distribution of <i>Tabernanthe iboga</i> Baill. (Apocynaceae) in Gabon with inhomogeneous point process models and presence-only data	Oral	BOUROBOU BOUROBOU Judi Armel
44	Summer 2025 « Coping with Climate Extreme » (CC-Extreme), Germany, September	Training	SONON Bienvenu
45	Tropentag 2025 hybrid conference, Germany, September	Training	SONON Bienvenu
46	Artificial intelligence for rainy season forecasting : A comprehensive analysis, Benin, July	Oral	SONON Bienvenu



A woodland of *Isoberlinia doka* and *Isoberlinia tomentosa* in the Wari-Maró forest reserve. © LABEF

APPENDIX 2.

Abstracts of published scientific papers in peer- review journals in 2025

Bayesian inference and impact of parameter prior specification in flexible multilevel nonlinear models in the context of infectious disease modeling

Adéoti O.M., Diop A., Glèlè Kakaï R.

Mathematical Biosciences and Engineering, 22(4), 897–919

DOI: <https://doi.org/10.3934/mbe.2025032>

Bayesian flexible multilevel nonlinear models (FMNLMs) are powerful tools to analyze infectious disease data with asymmetric and unbalanced structures, such as varying epidemic stages across countries. However, the robustness of these models can be undermined by poorly designed estimation methods, particularly due to uncertainties in prior distributions and initial values. This study investigates how varying levels of prior informativeness can influence the model convergence, parameter estimation, and computation time in a Bayesian flexible multilevel nonlinear model (FMNLM). A simulation study was conducted to evaluate the impact of modifying prior assumptions on posterior estimates and their subsequent effects on the interpretations. The framework was applied to COVID-19 data from Francophone West Africa. The results indicate that accurate, informative priors enhance the prediction performance with minimal impact on the computation time. Conversely, non-informative or inaccurate priors for nonlinear parameters led to lower convergence rates and a reduced recovery accuracy, although they may remain viable in standard multilevel nonlinear models.

Keywords: Non-linear mixed models; infectious disease; sensitivity; epidemic dynamic; Bayesian.

Climate change may shift the diet of the African savanna elephant: Preliminary results for 14 food tree and shrub species in the WAPOK transboundary ecosystem, West-Africa

Agounde G., Salako K.V., Idohou R. A. F., Sode A. I., Mensah S., Dimobe K., Assogbadjo A.E., Glèlè Kakaï R.

Global Ecology and Conservation, 58, e03468

DOI:

<https://doi.org/10.1016/j.gecco.2025.e03468>

Climate change through an increase in temperature and a reduction of rainfall constitutes a serious threat to the African savannah elephants *Loxodonta africana* Cuvier. Climate change can directly shrink suitable habitats of the main food resources of elephants; hence reducing their food availability. In this study, we assessed the present-day and future suitable habitat for 14 tree and shrub species previously identified as main components of the elephant diet in the W-Arli-Pendjari-Oti-Mandouri-Keran (WAPOK) ecosystem, the largest savannah ecosystem in West-Africa. Bioclimatic and soil data were used to build the present-day and future models under two representative concentration pathway scenarios: RCP4.5 and RCP8.5. We further explicitly accounted for dispersal constraints and compared “actually” colonized habitats to suitable habitats based on the traditional assumption of unlimited dispersal. Mean diurnal temperature range, isothermality, temperature seasonality, annual temperature range, annual precipitation, number of dry months, and soil were the seven most important drivers of the distribution of the species. However, their relative importance varied greatly among species. Nevertheless, the annual precipitation had a high contribution (47–77 %) for nine out of the 14 species (~ 65 %). Compared to present-day, results showed a moderate decrease in suitable habitats for seven out of the 14 species under scenarios RCP4.5 (1.30 – 12.95 %) and RCP8.5 (1.89 – 17.21 %). The remaining species, namely, *Tamarindus indica*, *Annona senegalensis*, *Vitex doniana*, *Vachellia sieberiana*, *Kigelia africana*, *Adansonia digitata*, and *Borassus aethiopum* will experience an increase of 2.97 – 51.68 % (RCP45) and 2.58 – 53.55 %

(RCP85) of their suitable habitats. Incorporation of dispersal constraints in the models showed that 9.26 – 48.26 % of currently suitable habitats will be occupied, with the lowest and highest values for *T. indica* and *A. digitata*, respectively. The top five species with moderate probabilities (35–48 %) to colonize and occupy suitable habitats included *A. digitata*, followed by *V. sieberiana*, *V. doniana*, *D. microcarpum*, *P. erinaceus*, and *P. biglobosa*. Species with the lowest probability to colonize suitable habitats were *V. paradoxa*, followed by *K. africana*, *Khaya senegalensis*, *Balanites aegyptiaca*, *B. aethiopum*, and *T. indica*. This study shows that climate change, by reducing the availability of some food resources, may shift the diet of African savanna elephants. It further indicated that dispersal constraint is important in habitat suitability modeling. Finally, it provides valuable information on the potential impacts of climate change on key food resources of savannah elephants, which can guide conservation and management actions in the WAPOK ecosystem.

Keywords: Climate change; WAPOK, Habitat suitability modeling; Dispersal limitation; Species distribution modeling; Conservation.

Assessment of Smallholder Farmers' Mitigation Strategies to Climatic Hazards in the Inland Valleys of Central Benin: The Case of Drought and Flood

Akodekou A.D., Dossou-Yovo E.R., Salako K.V., Diarra S.T., Nehren U., Glèlè Kakai R.
In: Leal Filho W. et al. (eds.), *Climate Change, Food Security, and Land Management*, Springer Nature Switzerland AG, 1–21
DOI: https://doi.org/10.1007/978-3-031-71164-0_73-1

Floods and droughts pose significant climatic threats to the stability of Benin's agro-economic systems, particularly affecting the livelihoods of smallholder farmers in inland valleys. In the Sudano-

Guinean zone, where rainfed agriculture predominates, these regions are highly susceptible to climatic hazards such as drought and flooding. However, the dynamics, impacts, and mitigation measures associated with these hazards remain poorly understood. This study investigated the frequency and duration of drought and flood events and the mitigation measures adopted by 208 smallholder farmers across 26 inland valleys in Savalou, a commune with substantial agricultural potential. A mixed methods approach was used: climatic data (temperature and precipitation) from 1991 to 2021 were analyzed with the Standardized Precipitation-Evapotranspiration Index (SPEI) to assess drought and flood hazards, while socioeconomic data were collected through 52 focus group discussions and structured surveys involving the selected smallholder farmers. Statistical and clustering analyses were employed to identify trends, spatial distributions, and the factors influencing the adoption of mitigation measures. The results revealed that the south-eastern part of Savalou was particularly prone to flooding, with events lasting up to 7 months and a frequency of 37%, while the northern and central parts were more vulnerable to droughts, which could last up to 10 months and had a frequency of 53%. Severe droughts, such as those of 2001, and episodes of extreme humidity in 1991 and 2019 highlighted significant climatic variability, further exacerbating the vulnerability of local farmers. In response, smallholder farmers have implemented various mitigation strategies, including adaptive agricultural practices, ecological restoration efforts, and technological infrastructure improvements. Socioeconomic factors such as proximity to markets, membership in agricultural organizations, and support from external institutions influenced the adoption of these strategies.

Keywords: Climatic hazards; Agricultural lowlands; Smallholder farmers; Hazards mitigation; West Africa

Relative Performance of Model Selection Criteria for Cox Proportional Hazards Regression Based on Kullback's Symmetric Divergence

Dete C.H., Lokonon B.E., Gneyou K.E., Senou M., Glèlè Kakai R.

Journal of Probability and Statistics, 2025, 3808705, 1-16

DOI: <https://doi.org/10.1155/jpas/3808705>

The Cox proportional hazards model is one of the most widely used models to analyze time-to-event outcomes. The decision on the most suitable model for such data is an essential step in statistical analysis. For this purpose, different model selection criteria can be used under various assumptions. This study assesses the relative performance of new model selection criteria based on Kullback's symmetric divergence in the Cox proportional hazards model. For this purpose, we compared the Kullback information criterion (KIC) and the corrected KIC (KICc) with other information criteria such as the Akaike information criterion (AIC), corrected AIC (AICc), and Bayesian information criterion (BIC) using a Monte Carlo experiment. Simulations were run using scenarios resulting from the combination of sample size ($n = 30, 50, 100, 200, 300$), censoring percentage ($C = 5\%, 10\%, 15\%, 20\%, 25\%$, and 30%), and censoring distribution (uniform or exponential). The results revealed that the KIC family criteria favor models with more accurate predictive power, irrespective of sample size or censoring percentage. However, they tend to select more underfitted models, which means that the KIC family favors parsimonious models regardless of sample size or censoring percentage. A larger sample size ($n = 200, 300$) improves the performance of these criteria in choosing the true model, irrespective of the censoring percentage. However, AIC and AICc outperform the KIC family criteria for relatively small to moderate

sample sizes ($n = 30, 50, 100$) in selecting the true model (containing only the relevant covariates). In addition, BIC tends to favor underfitted models over the KIC family criteria. Variations in censoring percentage, sample size, and censoring distribution affect the performance of these criteria in identifying the true model. These findings suggest that KIC or KICc should be preferred for larger sample sizes and when prioritizing predictive accuracy of the model. For smaller sample sizes, AIC or AICc should be preferred, and BIC in scenarios where model parsimony is critical. It is important to note that no model selection criterion is optimal in all situations, as their performance varies depending on the context.

Potential impacts of future climate on twelve key multipurpose tree species in Benin: Insights from species distribution modeling for biodiversity conservation

Dogbo S.F., Salako K.V., Agounde G., Dimobe K., Adiko A.E.G., Gebauer J., Adou Yao C.Y., Glèlè Kakai R.

Trees, Forests and People, 19, 100744

DOI:

<https://doi.org/10.1016/j.tfp.2025.100744>

The global decline of biodiversity threatens ecosystem stability and human well-being. This study modeled the future suitable habitats of twelve key multipurpose tree species (MPTS) in Benin under two climate scenarios, Shared Socioeconomic Pathways 245 (SSP245) and 585 (SSP585), based on a 2070 horizon. The research focused on peri-urban areas (Cotonou, Abomey, Savalou, Parakou, Natitingou, and Kandi) and the protected areas network in Benin. We evaluated environmental variables influencing MPTS distribution, projected habitat changes, identified hotspots, and compared impacts on native versus non-native species. Four modelling algorithms—Generalized Additive Models, Generalized Linear Models, Maximum

Entropy, and Random Forest—were used. Climate factors, particularly isothermality (Bio3) and annual precipitation (Bio12), predominantly influenced the distribution of the studied species. The models performed well, with a mean Area Under the Curve (AUC) of 0.88 and a mean True Skill Statistic (TSS) of 0.64. Projections indicated a decline in suitable habitats for 67% of species, minor changes for 8%, and increases for 25%. The effectiveness of protected areas was mixed, with species showing varied responses. Savalou and Abomey peri-urban areas emerged as key conservation hotspots, underscoring the need to shift conservation focus to these areas. Native species showed greater resilience to future climate conditions, emphasizing the importance of native species and species-specific conservation strategies under changing climates. These findings are relevant for promoting multipurpose tree species in Sub-Saharan Africa for sustainable ecological and socio-economic development.

Keywords: Agroforestry multipurpose tree species; habitat suitability modeling; peri-urban areas; protected areas; biodiversity conservation; climate change; Benin.

Impact of Box-Cox Transformation Technique on the Bayesian Maximum Entropy (BME) Prediction Accuracy

Gongnet E.E., Vihotogbé R., Agbangba E., Affossogbé T., Djondang K., Glèlè Kakaï R.

JP Journal of Biostatistics, 25(1), 127–144

DOI:

<https://doi.org/10.17654/0973514325006>

This study investigated whether increasing the normality of an attribute using Box-Cox transformation improves Bayesian Maximum Entropy (BME) prediction accuracy. Furthermore, we examined if BME accuracy is affected by sample size or spatial dependence. For hard data, the unconditional sequential approach was used to simulate symmetric data (skewness = 0) and positively skewed data (skewness: 1, 3, 6, and 9) with sample

sizes ranging from 100 to 500 at intervals of 50. Soft data was randomly distributed throughout a unit square with a width of 1.5. Data were then transformed using the Box-Cox transformation. Prediction accuracy was assessed using the Mean Squared Error (MSE) and bias, and transformation methods were compared using Multivariate Analysis of Variance (MANOVA). The results showed that BME accuracy is affected by transformation methods but not by sample size or spatial dependence. However, when comparing transformed data with untransformed data, the MSE and bias of the untransformed data ($\lambda = 1$) were closer to zero than those of the transformed data ($\lambda \neq 1$). As a result, the study concluded that BME is robust to skewness, sample size, and spatial dependence.

Keywords: Box-Cox transformation; skewness; spatial dependence; Bayesian maximum entropy.

Provenance and Tree-to-Tree Differences in Germination Performance of *Balanites aegyptiaca* (L.) Delile: Insights for Domestication and Selection

Kolawole M.A., Salako K.V., Akakpo A.D.M., Noulèkoun F., Assogbadjo A.E., Glèlè Kakaï R., Dimobe K.

Heliyon, 11, e42279

DOI:

<https://doi.org/10.1016/j.heliyon.2025.e42279>

Identifying the best genetic material across provenances and genotypes, particularly for vigorous seedling production, is a key aspect of domestication programs. This study aimed to (i) assess provenance and tree-to-tree differences in the germination performance of *Balanites aegyptiaca* and (ii) identify mother trees with the best germination performance for seed sourcing. A total of 1440 ripe fruits were collected from 36 mother trees in two provenances (Karimama and Tanguieta) in Benin and one provenance (Mouhoun) in Burkina Faso. A germination trial was

conducted using a split-plot design over 30 days. Differences among provenances and trees were assessed based on three metrics of germination performance: final germination percentage (FGP), mean germination time (MGT), and germination index (GI), using generalized linear models and linear mixed-effects models. Phenotypic variability, heritability, and genetic advance of *Balanites aegyptiaca* based on these metrics were further evaluated. Results showed that FGP, MGT, and GI varied significantly among provenances. FGP and GI exhibited considerable variation among provenances (44.7% and 38.9%, respectively) and among mother trees (48.2% and 46.7%, respectively). High phenotypic coefficient of variation (>67%), genotypic coefficient of variation (>63%), broad-sense heritability (>80%), and genetic gain (>100%) were observed for FGP and GI, indicating significant additive genetic effects for these metrics. Eight mother trees from Mouhoun, four from Karimama, and four from Tanguieta were identified as the best performers based on final germination percentage. The study showed that selection based on FGP and GI can be used to identify elite genotypes for domestication and improvement programs for *Balanites aegyptiaca*.

Keywords: Indigenous edible trees; seed propagation; genetic variation; heritability; desert date; West Africa.

Morphological Variability of *Pterocarpus erinaceus* Poir. Along a Climate Gradient in Burkina Faso, West Africa: Implications for Conservation and Domestication

Konda B., Dimobe K., Salako K.V., Dembélé J.B., Boussim I.J.

Genetic Resources and Crop Evolution, 72(6), 6597–6610

DOI: <https://doi.org/10.1007/s10722-024-02310-x>

This study investigates the morphological variability of *Pterocarpus erinaceus* Poir. across three climate zones in Burkina

Faso, West Africa. A total of 90 trees were analyzed using 10 morphological traits, and the data were evaluated using univariate and multivariate statistical methods. The results showed that trees in the Sudanian zone exhibited significantly larger morphological characteristics compared to those in other zones. In this zone, the average basal diameter was 42.45 ± 3.03 cm, crown diameter was 6.01 ± 0.23 m, and total height reached 12.13 ± 0.47 m, which is likely linked to the higher annual rainfall (exceeding 1000 mm) compared to other climatic regions. In contrast, individuals in the Sahelian zone displayed adaptations to arid conditions. Trees in this zone had longer average fruit lengths (4.24 ± 0.43 cm) compared to those in the Sudanian zone but showed lower fruit weights (0.29 ± 18 g). High coefficients of variation were observed for traits such as basal diameter (CV = 40%), diameter at breast height (CV = 34%), and seed weight (CV = 90%), indicating significant phenotypic plasticity and the species' potential to adapt to environmental variation. Clustering analysis identified three distinct morphological groups. The study highlights the resilience and adaptive capacity of *Pterocarpus erinaceus* to environmental changes and provides valuable insights for its conservation and domestication. Genotypes from the Sudanian regions are particularly recommended for reforestation and sustainable management projects.

Keywords: Burkina Faso; conservation; *Pterocarpus erinaceus*; variability; morphological traits.

Contribution of the Ramsar Convention to the Conservation of West-African Mangroves: A Case Study in Benin

Kochoni B.I., Salako K.V., Danquah J.A., Sinsin C.B.L., Mensah S., Glèlè Kakai R.

Wetlands Ecology and Management, 33, 15

DOI: <https://doi.org/10.1007/s11273-024-10026-z>

Given the essential role played by mangroves in the well-being of humanity, their conservation and wise use are essential to ensure their sustainability. The Ramsar Convention, an intergovernmental treaty that provides a framework for national action and international collaboration for the conservation and wise use of wetlands and their resources, falls within this context. In Benin, mangroves are restricted to two main blocks, designated as Ramsar sites in 2001. However, the evolution of mangroves before and after the declaration of these Ramsar sites is not well understood in terms of the effectiveness of the Ramsar Convention in their conservation and sustainable management. This study analyzed the changes in mangrove extent before and after their designation as Ramsar sites. Mangroves were identified using a Random Forest algorithm applied to Landsat satellite images from 1986, 2001, and 2022. The overall classification accuracy ranged from 0.91 to 0.96. The mangrove area in Benin was estimated at 5117 ha (94.6% in site 1017) in 1986, 2538.5 ha (95.4% in site 1017) in 2001, and 3052.4 ha (96.4% in site 1017) in 2022. Between 1986 and 2001, mangrove loss reached 50% and 57.4% in Ramsar sites 1017 and 1018, respectively. In contrast, from 2001 to 2022, mangroves increased by 21.4% in Ramsar site 1017, while a loss of 5.3% was recorded in Ramsar site 1018. These contrasting dynamics may be linked to differences in human activities and restoration initiatives across the sites. The results suggest that the designation of mangrove areas as Ramsar sites may have contributed to reducing mangrove loss and supporting their conservation.

Keywords: Mangroves; Ramsar sites; Google earth engine; Random forest; Intensity analysis; Land use land cover.

Tropical Rainforest Agroecosystems Sustainability by Efficient Soil Fertility and Water Management: Case of “Trois Rivières” Forest Reserves in Benin

Lokossou R.S., Akponikpè I.P.B., Matilo A.O., Davakan R., Glèlè Kakai R., Ganglo J.C., Mensah G.A.

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The current work highlights how to enable smallholders, depending on the “Trois Rivières” rainforest agroecosystems in Benin, to increase their crop yields on marginal land through sustainable agriculture practices and limit extensive agriculture. The most adopted soil and water conservation (SWC) measures and the most efficient and ecological fertilization practices were involved in two consecutive seasons of field experimentation (2016 and 2017) within the forest. The experiment design was set using a split-plot design fitted into a randomized complete block considering three factors: land-use practices (fallow age), the SWC measures, and farmers' fertilization practices. Data relating to soil fertility, leaf area index (LAI), soil moisture, maize biomass yield, maize grain yield, and daily rainfall within the season were analyzed by suitable tools and models in R software version 4.2.2. The large plowing perpendicular to the slope (LP), which is more economically viable, also allows better conservation of the soil moisture content by increasing its average by up to 3.93% compared to other SWC measures. It also favors a better development of maize crops in early fallow (low-fertility lands). Consequently, LP induced the highest biomass and grain yield during the two experiment seasons by increasing the average grain yield up to 27.3% of other plowing. LP also allows obtaining similar biomass and grain yield on low-fertility land (early fallow) as much as on high-fertility land (late fallow). Moreover, mineral microdosing fertilizer combined with manure (MDB), which consumes half of the mineral fertilizer than the recommended dose (RD), seems to be more efficient and more ecological. Thus, an application of MDB under the LP might be an economic and ecological solution to

improve the yield on the marginal land towards limiting extensive agriculture around “Trois Rivières ” forest reserves agroecosystems. There is therefore a possibility to increase agricultural productivity while halting deforestation. However, in the logic of “conservation agriculture” and biodiversity conservation, it is important to still improve those practices to make them more sustainable.
Keywords: Microdosing soil fertility; forest agroecosystems sustainability; “Trois Rivières” forest reserves; soil and water conservation; Benin.

Tree populations show low regeneration of valued species in West Africa

Lykke A.M., Rømer N., Gonzalez P., Glèlè Kakaï R., Rabiou H., Amegnaglo K.B., Ganaba S., Sambou B., Niang F., Herault B., Tang Guuroh R., Ouobam P., Yaméogo J.T., Traoré L., Sinsin B., Amahowe O.I., Baya S.S., Houehanou T.D., Houessou L.G., Gouwakinnou G.N., Yetein M.H., Tanko B., Ouédraogo A., Ouédraogo I., Taitar P., Amanis B.H.K., Coulibaly B., Kouyaté A.M., van Damme P., Vanhove W., Mahaman A., Bonache C., Sambou S., Soumana I., Amanz A., Maârouhia I.M., Barfod A.S.
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Tree populations have declined substantially in West Africa in recent decades, raising concerns since trees provide numerous ecosystem goods and services. Regional information on the population status of tree species could guide more effective conservation and regeneration of natural vegetation. Here, we report results of the first regional analysis of tree population structure across the Sahel and Sudan zones, a meta-study of vegetation inventories, including 23,586 individual trees sampled across nine countries. We evaluated current status and forecast future trends of 16 species and one genus of trees of

ecological and socio-economic importance. Size class distribution (SCD) reflects the population structure of an individual species and can provide early warning of composition change and population decline. SCD is analysed widely at a local scale, but analysis at a regional scale is needed to detect widespread population changes. Many native species lacked trees in the smaller size classes, implying unsustainable populations and future decline. Some species show sound regeneration at the regional scale, but high variation among sites. Eight species, including *Adansonia digitata* and *Azelia africana*, show regional declines in regeneration and risks of future extirpations. Four of these severely lack regeneration. Protected areas show higher tree regeneration, but protected status did not assure good regeneration. Our results identify priority tree species across West Africa, indicate a more urgent need for conservation and regeneration of native tree species, and highlight the benefit of effective conservation. More widespread protection could increase tree populations, conserving biodiversity, and ecosystem services essential for people's livelihoods.

Keywords: Conservation; Degradation; Regional analysis; Size class distribution; Sahel and Sudan zones; Tree population structure

Progress of in situ conservation and use of crop wild relatives for food security in a changing climate: a case of the underutilised *Vigna Savi*

Manda L., Idohou R., Agoyi E., Agbahoungba S., Salako K.V., Agbangla C., Adomou A.C., Assogbadjo A.E.

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Crop wild relatives (CWRs) - wild plant taxa genetically closely related to domesticated plants - are considered an alternative pathway to solving global food insecurity in a changing climate. However,

their potential contribution is undermined by fundamental knowledge gaps in taxa diversity, distributions, taxonomic affiliations, conservation strategies, and valuable traits. To address these gaps, we reviewed the literature on the progress made between 2000 and 2021 in support of in situ conservation and use of CWRs under the changing climate in five thematic areas focusing on the genus *Vigna*: (1) species diversity, global distribution, conservation status, gene pools, and importance of the genus; (2) CWR-in situ conservation protected area debate; (3) cultivation and domestication of CWR populations; (4) adaptive response to drought stress; and (5) adaptive response to *Striga* stress. We report that 104 *Vigna* CWR species in five subgenera, *Ceratotropis*, *Haydonia*, *Lasiosporon*, *Plectotropis*, and *Vigna*, are distributed mostly in Africa and Asia. Nine species are domesticated while six are threatened. *Vigna* gene pools remain poorly understood. Many *Vigna* CWRs provide various ecosystem services for human and environmental health. Attention is increasing towards in situ conservation of CWRs, within and outside protected areas, and complemented by ex situ conservation approaches. Several *Vigna* CWR taxa exhibit good agronomic traits for potential cultivation and neo-domestication. Many taxa have demonstrated tolerance to drought stress and race-specific *Striga* resistance. We conclude that if effectively conserved and used, *Vigna* CWRs can contribute to sustainable and climate-resilient food systems, either as wild edible plants, new plants for neo-domestication, or novel sources of genetic material for use in pre-breeding programs to improve the resilience, quantity, and quality of *Vigna* domesticates under the changing climate. This study could stimulate further research and policy change for effective CWR conservation and use for sustainable food security in a changing climate.

Keywords: biodiversity; climate-resilient food systems; crop wild relatives; drought

stress; ecosystem services; in situ conservation; *Striga* stress; Zero hunger.

Assessing the potential seasonality of COVID-19 dynamic in Africa: a mathematical modeling study

Montcho Y., Amoussouvi K.T., Atchadé M.N., Salako K.V., Hounkonnou M.N., Wolkewitz M., Glèlè Kakāi R.

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The infection by SARS-CoV-2 appeared for the first time in 2019, and several factors that influenced its spread remain unclear. Although many studies investigated the seasonality of this infection, most of the findings are controversial across time and geographical space, highlighting the need for further research, particularly in Africa, where the low number of cases was surprising. This study aims to investigate the potential seasonality of infection by SARS-CoV-2, considering three main climate zones, namely tropical, arid, and temperate zones. To do so, an extended SEIR model of eight classes, including susceptible (S), vaccinated susceptible (Sv), exposed (E), pre-symptomatic infectious (Ip), asymptomatic infectious (Ia), symptomatic infectious (Is), detected infectious (Id), and recovered (R), was developed considering 25 African countries. The model accounted for seasonality through the transmission rates using a cosine seasonal forcing. After estimating the seasonality amplitudes of the transmission rates for each country, a Kruskal-Wallis H test was used to check for variation among the climate zones. Then, a sensitivity analysis was carried out to assess the effect of seasonality amplitudes of the transmission rates on the control reproduction number (R_c) using the Partial Rank Correlation Coefficient. Results showed that the seasonality amplitude of the asymptomatic transmission is one of the main driving

factors of the pandemic, and more so in the Temperate zone, where the weather is mostly cold. Therefore, in the event of a re-emergence of SARS-CoV-2 in the temperate zone, in addition to isolating and caring for symptomatic individuals, preventing the spread of SARS-CoV-2 from asymptomatic infectious individuals through mass testing can significantly reduce the burden of the pandemic, especially in the cold season. The same measure can be applied in other regions of the continent, particularly during cold and rainy periods.

Keywords: Seasonality; Pandemic; Africa; Mathematical modeling

Contrasting ecological mechanisms mediate the impact of land conversion on ecosystem multifunctionality

Noulèkoun F., Mensah S., Kim H., Houndonougbo J.S.H., Mensah M., Lee W.K., Son Y., Khamzina A.

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Land use/cover (LULC) changes have unequivocally affected biodiversity and ecosystem functioning, with enormous repercussions for human well-being. However, the mechanistic ecological mechanisms underlying the impact of land conversion on ecosystem multifunctionality (EMF) remain insufficiently examined from the perspective of multiple biodiversity attributes in dryland regions with increasing deforestation rates. We investigated how the conversion of natural forests and savannas to agroforestry parklands alters the relationships between multiple biodiversity attributes (taxonomic, functional, phylogenetic, and structural) and EMF, while accounting for the effects of environmental factors in the dryland landscapes in Benin. We used forest inventory data from 145 plots spanning forests, savannas, and agroforestry parklands and assessed the implications

of three land conversion scenarios. We quantified EMF using eight functions that are central to primary productivity and nutrient cycling. We found that EMF was positively related solely to structural diversity in forests. The conversion of forests and savannas to agroforestry parklands decreased EMF both directly and indirectly. The indirect effects were mediated by two contrasting biodiversity effects. When forests were converted to agroforestry parklands through savannas, indirect effects were driven by shifts in functional composition towards the dominance of species with acquisitive traits. In contrast, species diversity reduction explained the indirect effects when savannas were converted to agroforestry parklands. The aridity index and soil texture influenced biodiversity attributes, but not EMF. The present study provides evidence that the biodiversity–EMF relationship is dependent on the LULC type and was evident only in the natural ecosystem through the effects of structural diversity, thereby emphasizing the importance of enhancing structural diversity for promoting EMF in forests. Our findings also demonstrate that land conversion weakened natural EMF through biotic homogenization resulting from two contrasting biodiversity-related mechanisms, including loss of species diversity and dominance of species with acquisitive resource-use strategy.

Keywords: Agroforestry parkland; carbon stock; mean pairwise distance; soil phosphorus content; structural equation modeling; West Africa.

Wetlands of Benin (West Africa): Biodiversity, Livelihoods, and Conservation

Salako K.V., Dassou G.H., Gnansounou S.C., Zanvo M.G.S., Akodekou A.D., Glèlè Kakaï R. In: Pullaiah T. (ed.), **Wetlands of Tropical and Subtropical Asia and Africa: Biodiversity, Livelihoods and Conservation**, Chapter 8, John Wiley & Sons

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Wetlands are among the most productive and dynamic ecosystems worldwide. Despite the high man-made and climate-related pressures they face in recent times, limited information exists in Sub-Saharan Africa on their capacity to conserve biodiversity, and the extent to which they are under threat. In this chapter, we drew insights from document reviews, primary data, and over 10 years of experience working in wetlands across the country to report on the typology, biodiversity, conservation status, and threats faced by wetlands in Benin, a coastal state located in West Africa. Results indicated that six major wetlands, namely, open water bodies (ocean, lake, and rivers), mangroves, swamp forests, marshy meadows, inland valleys, and riparian forests. In total, 116 plant species and over 100 animal species were identified in wetlands in Benin. The major uses of these ecosystems include exploitation for food production, fuelwood collection, medicinal plant collection, and service wood collection. Wetlands in Benin also benefit from various conservation measures ranging from the establishment of reserves and marine protected areas to the use of traditional methods. Anthropogenic threats such as excessive wood extraction, increasing urbanization, overfishing, overgrazing, illegal and unregulated fishing, waste and agricultural pollution, poaching, hydrological constraints, sedimentation, agricultural expansion, invasive species, misguided management policies, and mining were identified as major drivers of wetlands degradation in Benin. Therefore, there is a need to combat these threats through community engagement and scientifically sound policy initiatives for the protection and sustainable use of wetlands in Benin.

Effects of weather scenarios and fertilizer on maize growth and yield: Insights from a greenhouse experiment

Tahi S.P.C., Salako K.V., Houndji V.R., Glèlè Kakaï R.

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Maize is a major crop for food security, but its cultivation is threatened by climate change. Climate may affect the response of maize to fertilizer. This study examined the impact of weather parameters in combination with fertilizer types on maize growth and yield parameters in Benin. The experiment involved two sets of climatic scenarios. Scenario 1 (weather 1) had a moderate range of minimum and maximum temperatures and maximum humidity suitable for maize cultivation in Benin. Scenario 2 (Weather 2) featured a broader range of parameter values below and above those of Weather 1. Five types of fertilizers were tested: Organic (Cow dung), Chemical (NPK), Intermediate 1 (mixture of high NPK and low Cow dung), Intermediate 2 (mixture of middle NPK and middle cow dung), and Intermediate 3 (mixture of high cow dung and low NPK). These factors were combined in a split-plot design and data were collected on maize germination, growth, and yield variables. Models such as DNNsurv, Cox, linear mixed effect, and decision trees were used for data analysis. Results revealed that maize seeds had a higher probability of germination between 2 to 5 days after sowing, with over 80% of the seeds germinating the fifth day. Intermediate 1 and organic fertilizers were particularly effective in promoting maize growth, resulting in larger diameters and heights. Organic, chemical, and intermediate 1 fertilizers led to higher yields under weather scenario 2, while intermediate 3 and organic led to higher yields under weather 1, suggesting that organic fertilizers could be more sustainable and cost-effective than mineral fertilizers. Additionally, Weather 2

was associated with higher maize yields suggesting that, a relatively broader range of climate parameters would positively affect maize yield. These findings can assist farmers and policymakers in making well-informed decisions regarding the most suitable fertilizers to use under various weather conditions, maximizing their yield and profits.

Seeds of Sustainability: Unveiling the Population Dynamics of *Carapa procera*, *Lophira lanceolata*, and *Pentadesma butyracea* for Adaptive Oilseed Value Chains

Tiétiambou F.R.S., Dimobe K., Salako K.V., Lankoandé B., Ouédraogo A.

African Journal of Ecology, 63(2), e70020

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Carapa procera, *Lophira lanceolata*, and *Pentadesma butyracea* are important non-timber forest products providing species with promising value chains of their oils. To assess whether traditional uses of these species are sustainable, this study analysed their population structure and regeneration patterns in non-protected sites. Three sites where the fruits of these species are exploited for oilseed production and trade were selected for each species, and 135 plots with 665 subplots were established for adult and regeneration inventories, respectively. The population structure and regeneration patterns were assessed using dendrometric characteristics (tree diameter at breast height—dbh and height), population density, and metrics of stability. *C. procera* had the highest dendrometric values at Diossogo and Koloko for adult individuals. Its populations were generally stable across all sites. For *L. lanceolata*, the highest dendrometric values were observed at Natindougou. However, populations at both Natindougou and Nafanasso showed signs of disturbance and instability. For *P. butyracea*, the highest values for mean diameter and Lorey's height of adult

individuals were recorded at Sokouraba. Population densities were highest at Nafanasso, but populations were disturbed at Sokoroni and Sokouraba, with stability observed across all sites. Given the current condition of the stands of each species, implementing management actions tailored to site-specific conditions is essential to ensure the long-term sustainability and productivity of these valuable species in their natural habitats.

Keywords: Burkina Faso; regeneration; resources availability; stability; sustainable management

Bayesian flexible multilevel nonlinear models in infectious disease modeling using non-informative priors

Adéoti O. M., Diop A., Hounkonnou M. N., Glèlè Kakaï R.

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Accurate modeling of infectious diseases is essential for understanding and predicting pandemic trajectories and informing effective public health interventions. The complex and heterogeneous nature of epidemic data often pose challenges for traditional modeling approaches. This study introduces a novel approach using Bayesian flexible multilevel nonlinear models (SMSN-NLMMs: scale mixtures of skew-normal and SNP-NLMMs: semi-nonparametric approaches), to address these challenges. To evaluate the model performance, we conducted rigorous simulations in various epidemic scenarios and applied the models to real-world COVID-19 data from seven West-African countries. The results demonstrate that both SMSN-NLMMs and SNP-NLMMs significantly out-perform standard nonlinear mixed models (NLMMs) in accurately recovering key epidemic

parameters. While both models exhibit similar performance with large sample sizes, SMSN-NLMM and SNP-NLMM with expansion order $K = 1$ demonstrates greater flexibility for daily reported data. Conversely, SNP-NLMM with $K = 2$ achieved a better fit for weekly simulated epidemic data. When applied to the COVID-19 data, the models produced results that align with the true estimated transmission parameters, including the turning point, the final size of the outbreak, and the basic reproduction number (R_0). The paper also explores the convergence of the Hamiltonian Monte-Carlo (HMC) method in Stan and model sensitivity to prior distributions.

Keywords: Bayesian approach; epidemic dynamics; heterogeneous data; infectious disease modeling; nonlinear mixed models.

Variation in the potential impacts of climate change on the baobab in Sub-Saharan Africa: A continental analysis across major climate zones

Agbohessou M., Salako K.V., Agounde G., Mensah S., Ngom A., Noba K., Glèlè Kakai R., Assogbadjo A.E.

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Baobab, *Adansonia digitata* L. is a widespread multipurpose savannah tree in Africa. Although previous studies highlighted the potential impacts of climate on the species, we still lack sufficient understanding of how regional variation in ecological tolerance might influence its future resilience across the continent. This study used ensemble species distribution models (SDMs) to forecast suitable habitats for *A. digitata* under two climate scenarios (SSP 245 and SSP 585) for 2050 and 2070, across four climate zones: humid, subhumid, semi-arid, and arid. We built both whole-species and climate-zone-specific models to assess the role of niche differentiation on

projected habitat suitability. Isothermality (36.75 %) was the most influential variable in the whole-species model, while soil properties (26.41 %) constrained habitat suitability. In zone-specific models, key drivers changed with the zone: precipitation of the driest month and soil properties dominated in the subhumid zone; annual precipitation and soil properties in the semi-arid; maximum temperature and annual precipitation in the humid; and mean diurnal temperature range in the arid. Niche overlap between zones was low (Schoener's $D = 0.06 - 0.13$), suggesting a broad climate tolerance. Whole-species models predicted slight habitat loss (0.5 – 1.12 %) by 2070, especially under SSP 585, whereas zone-specific models showed increases (1.48 – 3.13 %), irrespective of the scenarios and horizons, particularly in the humid zone. These findings underscore the importance of accounting for regional variation in SDMs for widespread species. Baobab's broad climatic tolerance may support resilience to climate change, though reciprocal transplant experiments are needed to disentangle the role of local adaptation from plasticity.

Keywords: *A. digitata*; Species distribution models; Regional variation; Climate change

Hydrological repair and invasive grass removal restore *Rhizophora racemosa* mangrove communities in West Africa

Agraz Hernandez C.M., Houndjinou E., Reyes Castellanos J.E., Chan Keb C.A., Osti Saénz J., Chavez Barrera J.C., Etienne J., Glèlè Kakai R., Puschendorf R.

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Mangrove ecosystems face significant threats from climate change and human activities. In West Benin, the invasive grass *Paspalum vaginatum* disrupts sedimentation and hydrology, creating anoxic conditions and nutrient imbalances. To address this, we

implemented a cost-effective restoration strategy focused on hydrological repair, engaging local communities to excavate 26 artificial channels and clear 19 existing ones, restoring tidal flow to 30 ha of degraded mangrove forest. Of this, 20 ha were planted with *Rhizophora racemosa* propagules, while 10 ha remained unplanted due to unsuitable micro-topographic conditions. This intervention, costing \$1394.3 USD per hectare, adjusted sediment levels to match natural micro-topography, enabling hydrological recovery and suppressing *P. vaginatum*. The return of *Sesuvium portulacastrum* stabilized sediments, improved nutrient retention, and facilitated mangrove regeneration. Over 24 months, restoration efforts improved physicochemical parameters, reduced ammonium and acidity, and supported the planting of 250,000 *R. racemosa* propagules at 25 propagules/m² across 20 ha. At 785 days post-planting, survival reached 90%, promoting natural recolonization by mangroves along channel edges and by *S. portulacastrum* in adjacent unplanted areas. The 10 ha not reforested exhibited low *P. vaginatum* colonization, reinforcing the effectiveness of hydrological repair. This study presents a scalable, low-cost restoration model that integrates hydrological repair and pioneer species facilitation to enhance mangrove recovery. While still in early recovery, this community-driven approach establishes a strong foundation for long-term ecological restoration.

Keywords: community-driven restoration; environmental stress; hydrological repair; invasive plant; mangroves.

Phylogenetic diversity and seed pod traits altered seed pod fate in disturbed environments

Akin Y.Y., Gaoue O.G.

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Understanding frugivory and seed dispersal is crucial in predicting plant population dynamics. Fruit fate can be altered by the environment, community diversity, and fruit traits. However, our understanding of how environmental drivers, including climate and disturbance, mediate the effect of seed traits and plant community diversity on fruit fate in dry tropical ecosystems is still limited. We conducted a removal experiment by tracking 493 pods of *Prosopis africana*, a species dispersed by rodents, in five tropical forest sites in Benin. Each seed pod was numbered, weighed, and measured for length, and then randomly distributed in a circular subplot beneath ten mother trees at each site. For each pod, we recorded whether it was removed from the subplot and estimated the proportion of the pod (based on the length) that was not eaten but removed from the subplot (seed pod dispersal). We also estimated the removal distance of partially eaten pods out of the subplot (dispersal distance) and the proportion of pods eaten (pod predation). We developed Bayesian models to test how the fate of seed pods is driven by pod traits and plant community diversity across contrasting environments. We found that seed pod dispersal agents act simultaneously as predators and dispersers, reflecting a dual-role interaction. Dispersal and predation were strongly context-dependent. Additionally, in communities with high phylogenetic diversity, pod predation was stronger in the highly disturbed sites of the dry region than in other environments. Our results highlight context-dependent seed pod dispersal, with disturbance severity and climate harshness facilitating seed pod predation. This differential seed fate across environmental gradients can shape transient population dynamics.

Keywords: Bayesian model; Phylogenetic diversity; Seed pod fate; Tropical tree

The influence of household socioeconomic profiles on the use of mangrove resources along the Benin coastline

Akoton T.P., Hountondji Y.C., Sourou B.N., Tcheton S., Wedjangnon A.A., Houëtchégon T., Sogbossi S.E., Salako K.V., Ouinsavi C.

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Introduction: The mangrove ecosystems are crucial marine ecosystems, providing various ecological and economic benefits to local communities. This study aims to analyze the influence of household socioeconomic profiles on mangrove ecosystems resources in Benin. Methods: Based on semi structured interviews, households were surveyed in localities. The Specific Multiple Correspondence Analysis (spMCA) combined with Hierarchical Ascendant Classification (HAC) was used to analyze the socioeconomics, demographics, and environmental data collected. The priority scores of the surveyed households were used to perform the influence of households to mangrove resources by coupling HAC to Principal Component Analysis (PCA). Results: Five household categories (labeled CM-CM) were identified. They represent varying levels of vulnerability, access to resources, and modes of mangrove resource use. The household of CM are highly dependent on mangrove resources and distributed proportionally across the study subsectors whereas the CM household are the most vulnerable, located around the biosphere reserve, and facing land tenure insecurity, extreme poverty, and significant pressure on mangrove ecosystems. The household categories are strongly influenced by the dependency on biosphere reserve resources and sociolinguistic affiliation. The gender and education level play a secondary role on household categories structuring. Five groups of pressure factors on the mangroves were associated

with the different household categories. Salt farming, wood cutting, and backfilling of waterways are predominant for CM, CM, CM, and CM. Land overexploitation, depletion of fishery resources, and climatic factors are the mainly determinants for CM and CM. Land conflicts and declining agricultural yields are also mentioned by CM. Conclusion: These results highlight the need for differentiated mangrove management strategies, tailored to the specific socioeconomic characteristics of the households.

Co-management, reforestation, and awareness raising activities, represent strategic targets for sustainable conservation policies. Also, specific support measures, including the development of sustainable economic alternatives and improved access to basic services are needed. Taking this typology into account would improve the effectiveness and equity of environmental policies related to mangrove management.

Keywords: biodiversity conservation; ecosystem management; wetland; biosphere reserve; environment.

Modelling the impact of vaccination on cholera transmission dynamics under stratified populations and seasonality

Anteneh L.M., Glèlè Kakaï R., Zanzo S.D., Traore K.

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Different types of oral cholera vaccines (OCVs) are currently available in the global market to combat cholera epidemic. In most of developing countries, there is comparatively limited deployment of vaccination programs. In this study, we develop a non-linear deterministic mathematical model to investigate the dynamics of cholera in the presence of vaccination under stratified population, and taking into account the seasonality of

the disease dynamic. The model stratifies the total population into two strata based on level of exposure or individuals risk status. We use reported cholera data to estimate the values of model parameters using the least square method together with the `fminsearch` function in the MATLAB optimization toolbox. Sensitivity analysis was performed to identify the impact of vaccination on cholera transmission dynamics. Numerical results show that the reproduction numbers were 3.35 and 2.6 in more and less exposed population, respectively, with an average value of the whole population equal to 2.98. Specifically, our findings indicate that at least 70 % of the most exposed population needs to be vaccinated to halt transmission within that group, while a minimum of 62 % of the less exposed population must be vaccinated to halt transmission in this population. We further observe that the vaccination rate significantly impact the amplitude of the epidemic curves. Our findings suggest that vaccination of susceptible population stratified with a certain priority (e.g., level of exposure or individual's risk status) against the disease can reduce the transmission of cholera, potentially slowing the spread of the bacteria in a population.

Keywords: Infectious diseases; Mathematical modelling; Control reproduction number; Strata; Vaccination; Rainfall.

Utilitarian diversity and options for the sustainable use of the bush banana *Uvaria chamae* P. Beauv. in Benin (West Africa)

Daï E.H., Idohou R., Toyi S.S.M., Houndonougbo J.S.H., Azihou F.A., Ouédraogo A., Hotes S., Assogbadjo A.E.

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Background: The bush banana (*Uvaria chamae* P. Beauv.) is a wild edible fruit, but its population has declined recently in Benin. This study assessed the traditional knowledge and use of *U. chamae*, along with the key factors relevant to its conservation and sustainable management. The study reports (i) traditional knowledge and effective use of the species by local communities in relation to socioeconomic factors, (ii) local perceptions of threats to *U. chamae*, and (iii) conservation strategies suggested by local communities to ensure its sustainable use and management in Benin. **Methods:** This study was carried out in the Guineo-Congolian and Sudano-Guinean zones of Benin where the species occurs. The data were collected from June to December 2021. The study sites were selected based on the occurrence and geographical distribution of *U. chamae*, while taking into account the representativeness of the diversity of sociolinguistic groups in the overall sample. Semi-structured questionnaires were administered to 434 respondents belonging to 15 sociolinguistic groups living in the phytodistricts of *U. chamae* distribution. The relative frequency of citation of the different uses was analyzed in relation to the socioeconomic attributes of the respondents. A principal component analysis was performed to highlight the relationships between the different uses and the sociolinguistic groups. Finally, a linear model was used to assess the effects of the sociocultural factors of the respondents on the use values of *U. chamae*. **Results:** A total of 71 traditional use categories were identified for *U. chamae*, sixty of which were used by the respondents. Women and elderly members of the Fon, Aïzo and Mahi sociolinguistic groups, particularly those involved in traditional medicine and living in the phytodistrict of Plateau, were the primary users of *U. chamae*. The main use categories, summarized from all the respondents, were medicinal (97%), food (84.10%), magico-religious (52.92%), firewood (25.52%), and material for

handicrafts (7.30%). The most valued plant parts were roots, fruits, leaves, and branches. The main threats to *U. chamae* are largely due to human activities rather than climatic factors. **Conclusion:** This study revealed that *U. chamae* is a multipurpose shrub, mainly used in traditional medicine and as a food source. There is little consensus among local people about its medicinal uses. Investigating the nutritional, biochemical, and toxicological properties of *U. chamae* extracts could help to verify the claims attributed to the plant. Local communities suggested the promotion of home and botanical gardens as the main conservation measures to ensure the sustainable use and management of *U. chamae* in Benin.

Keywords: Traditional medicine; Wild edible fruits; Domestication; Forest resources; Local perception.

Modelling current and future suitable cultivation areas of cashew trees in Benin (West Africa) based on the major parasite and its parasitoid distribution under global climate warming

Dotonhoué C.F.G., Agounde G., Wedjangnon A.A., Ouinsavi C.

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The cashew tree is an essential source of income in West African households, especially in Benin. However, it faces declining productivity due to parasites and climate change. The insect *Oecophylla longinoda* (Latreille) is commonly used to control the cashew pest *Helopeltis schoutedeni* Reuter.; however, how climate change affects their distribution and how this can be used to identify suitable cashew cultivation areas remains a challenge. For this purpose, we used machine learning to identify suitable areas for cashew cultivation in Benin, considering occurrence points and

environmental factors that limit the distribution of cashew trees, the pest, and the beneficial insect. Globally, models performed well, with mean values of the area under the curve ranging from 0.76 to 0.97 and mean values of the true skill statistics ranging from 0.44 to 0.85. Both precipitation seasonality and isothermality influenced the spatial distribution of cashew trees in Benin; while the mean temperature of the warmest months and annual precipitation determined the distribution of *H. schoutedeni*. As for *O. longinoda*, the precipitation of the driest quarter and wind speed determined its distribution. Suitable areas for cashew cultivation in current conditions were mainly concentrated in the agricultural development pole 4 (ATDA 4), encompassing the municipalities of Savalou, Bassila, Bantè, Glazoué, Tchaourou, Ouèssè, Savè, Dassa, and Parakou. These suitable areas are expected to decrease by 15.16–28.47 % by 2070, with a shift towards the south, especially in agricultural development pole 5 (ATDA 5) and 7 (ATDA 7) under ssp245 and ssp585. These findings are relevant for decision-makers in the medium and long-term targeting of suitable cultivation areas of cashew trees in Benin.

Keywords: Tree crop management; *Anacardium occidentale*; *Oecophylla longinoda*; *Helopeltis schoutedeni*; Machine learning; Biogeography; Climate change.

From the table to the mill: a socio-cultural valuation of the dynamics in mangrove oyster exploitation in Togo Republic using qualitative methods

Gnansounou S.C., Akodekou A.D., Salako K.V., Houndjinou E., Apithy E., Glèlè Kakai R.

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With the increasing food insecurity and shortage in animal protein provision, affordable and healthy sources of seafood, such as mangrove oysters, have emerged as promising alternatives. However, increasing anthropogenic pressures compromise the sustainability of oyster sector in many developing coastal states. This study investigated the local importance and trends of mangrove oyster collection in Togo, West-Africa, using a socio-cultural valuation approach. The study employed qualitative-oriented methods such as informal conversation, focus group discussions, in-depth interviews, and participant observations, to understand the patterns of use and the dynamics in oyster exploitation in Togo. Results indicated that most people expressed a frequent consumption preference for mangrove oyster (95%), while a minority consume it rarely (5%). Participants in the study identified three main periods (past, present, and future) marked by varying patterns of harvesting and utilization of mangrove oysters. Unlike in the preceding years when all harvested oysters were processed for human consumption, a larger part of the resources collected (over 70%) are now reduced to poultry feed for animal consumption, predominantly due to phosphate-based pollution occurring in the area, which deteriorates the quality of the resource. This study serves as a preliminary appraisal for more quantitative research initiatives, and policy actions to rescue the oyster sector for the sustainability of mangrove resources, and the improvement of local people livelihoods and wellbeing in Togo and in West-Africa at large.

Keywords: Mangrove oysters; Pollution; Natural resources; Togo; West Africa

Gendered trends and barriers in agroforestry adoption in Benin (West Africa)

Kpoviwanou Houndjo M.R.J., Ouinsavi C., Alaye E.A., Wedjangnon A.A.

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This study analyzed agroforestry technologies adoption bottlenecks and how to address them in Benin. We combined satellite imagery (PlanetScope images 2015 and 2023) processed from object-oriented classification with socio-demographic surveys conducted with 360 farmers selected through purposive sampling. Structural equation modeling (SEM) was used to analyze the factors influencing farmers' agroforestry practices, and gendered technology adoption was assessed via chi-square tests. The results illustrated that in addition to farmers' perception ($\lambda = 0.654^{**}$), the structural equation modeling (SEM) indicated significant relations between level of formal education ($(\lambda = -0.431^*)$), farming experience ($\lambda = 0.654^{**}$), planting of cereals ($\lambda = -0.953^{***}$), legumes ($\lambda = 0.647^{***}$) and tubers ($\lambda = 0.385^*$), agro-ecological zones ($\beta = 0.501^{***}$), land acquisition by inheritance ($\lambda = 0.712^{***}$), limited access to land ($\beta = -0.012$) and farmers' agroforestry practices. Analysis of the trend in the adoption of technologies shows a predominance of agroforestry parks (adopted by 91% of male farmers and 71% of female farmers) and a low diversity of agroforestry technologies adopted by farmers. The dominance of this type of agroforestry indicates the fragility of the forest environment in Benin, as the growth of agroforestry parks corresponds to the increase in the loss of forest area. Additionally, 29% of the male farmers were using at least one new agroforestry technology, while only 9% of the female farmers were using these technologies. Similarly, the constraints analysis revealed that the lack of manpower is one of the more significant specific challenges faced by women. Capacity building and support through gender-specific approaches are therefore needed to better promote this practice.

Keywords: Agroforestry; Determinants; Adoption; Gender dynamics; Benin; West Africa

The global spectrum of tree crown architecture

Jucker T., Fischer F.J., Chave J., Coomes D.A., Caspersen J., Ali A., Loubota Panzou G.J., Feldpausch T.R., Falster D., Usoltsev V.A., Jackson T.D., Adu-Bredu S., Alves L.F., Aminpour M., Angoboy Ilondea B., Anten N.P.R., Antin C., Askari Y., Ayyappan N., Banin L.F., Barbier N., Battles J.J., Beeckman H., Bocko Y.E., Bond-Lamberty B., Bongers F., Bowers S., van Breugel M., Chanttrain A., Chaudhary R., Dai J., Dalponte M., Dimobe K., Domec J.-C., Doucet J.-L., Dupuy Rada J.M., Duursma R.A., Enríquez M., van Ewijk K.Y., Farfán-Rios W., Fayolle A., Ferretti M., Forni E., Forrester D.I., Gilani H., Godlee J.L., Haeni M., Hall J.S., He J.-K., Hemp A., Hernández-Stefanoni J.L., Higgins S.I., Holdaway R.J., Hussain K., Hutley L.B., Ichie T., Iida Y., Jiang H.-S., Joshi P.R., Kaboli H., Kazempour Larsary M., Kenzo T., Kloeppel B.D., Kohyama T.S., Kunwar S., Kuyah S., Kvasnica J., Lin S., Lines E.R., Liu H., Lorimer C., Loumeto J.-J., Malhi Y., Marshall P.L., Mattsson E., Matula R., Meave J.A., Mensah S., Mi X., Momo S.T., Moncrieff G.R., Mora F., Muñoz R., Nissanka S.P., Nur Hajar Z.S., O'Hara K.L., Pearce S., Pelissier R., Peri P.L., Ploton P., Poorter L., Pour M.J., Pourbabaie H., Ribeiro S.C., Ryan C., Sanaei A., Sanger J., Schlund M., Sellan G., Shenkin A., Sonké B., Sterck F.J., Svátek M., Takagi K., Trugman A.T., Vadeboncoeur M.A., Valipour A., Vanderwel M.C., Vovides A.G., Waldner P., Wang W., Wang L.-Q., Wirth C., Woods M., Xiang W., de Aquino Ximenes F., Xu Y., Yamada T., Zavala M.A., Zimmermann N.E.

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Trees can differ enormously in their crown architectural traits, such as the scaling relationships between tree height, crown

width and stem diameter. Yet despite the importance of crown architecture in shaping the structure and function of terrestrial ecosystems, we lack a complete picture of what drives this incredible diversity in crown shapes. Using data from 374,888 globally distributed trees, we explore how climate, disturbance, competition, functional traits, and evolutionary history constrain the height and crown width scaling relationships of 1914 tree species. We find that variation in height-diameter scaling relationships is primarily controlled by water availability and light competition. Conversely, crown width is predominantly shaped by exposure to wind and fire, while also covarying with functional traits related to mechanical stability and photosynthesis. Additionally, we identify several plant lineages with highly distinctive stem and crown forms, such as the exceedingly slender dipterocarps of Southeast Asia, or the extremely wide crowns of legume trees in African savannas. Our study charts the global spectrum of tree crown architecture and pinpoints the processes that shape the 3D structure of woody ecosystems.

Pruning leaf mineralization dynamic of three agroforestry species on two major soil types in Benin

Kakpo D.A.R., Bankolé E., Sossa E.L., Amadjì G.L., Dagbénonbakin D.G., Buri M.M., Glèlè Kakaï R.

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Agroforestry systems, involving tree species, store soil carbon through mineralization of litter, but few studies evaluate their potential to improve soil fertility. The objective of the study was to evaluate the mineralization rate of three most representative agroforestry species (*Parkia biglobosa*, *Vitellaria paradoxa* and *Vitex doniana*) biomass in Benin. Using

the litter bag technique, a trial was conducted on Ferrallitic soil and Tropical Ferruginous soil. A split-plot design with three replications was adopted. Data on total pruned dry matter biomass, total nitrogen (N), and total carbon (C) contents of residual litter were analyzed with R software. Findings indicated that pruning leaf decomposition varied significantly with time ($p < 0.001$), species ($p = 0.033$), soil [(68.38% for Ferrallitic soil over Tropical Ferruginous soil) ($p = 0.005$)] and, time-area interaction ($p = 0.017$). Ferrallitic soil, realized more nitrogen with *Vitex doniana* (97.92%) than *Parkia biglobosa* and *Vitellaria paradoxa* when Tropical ferruginous soil realized with *Parkia biglobosa* biomass the most (86.29%). However, *Vitex doniana* pruning leaf released more carbon (96.55%) than *Vitellaria paradoxa* and *Parkia biglobosa* on Ferrallisol soil. The highest N and C release rates were observed in the litter of *Parkia biglobosa* and *Vitex doniana* on tropical ferruginous soil respectively while the highest N and C release rates were observed in the litter of *Vitellaria paradoxa* and *Vitex doniana* respectively on Ferrallisol soil. To promote the plantation of native agroforestry species area *Vitex doniana* and *Parkia biglobosa* can be recommended on Ferrallisol soil while *Vitellaria paradoxa* and *Parkia biglobosa* on Tropical ferruginous.

Keywords: Forestry species, climate change, carbon, soil fertility, litter, decomposition.

Impact of Anthropogenic Activities and Climate Change on Carbon Stock in a West-African Mangrove

Kochoni B.I., Salako K.V., Dimobe K., Agounde G., Zanzo S.D., Danquah J.A., Glèlè Kakaï R.

Wetlands, 45:50

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Mangroves are important carbon sinks and thus play a crucial role in reducing

greenhouse gas emissions. In addition to anthropogenic disturbances, climate change is projected to affect carbon in mangroves, although the extent of this impact is poorly known in West-Africa. We focused on mangroves of Ramsar sites 1017 and 1018 in Benin and aimed to estimate the carbon stock in disturbed versus undisturbed mangroves and predict the impact of future climate on the spatial distribution of carbon stock in mangroves. Plot-based sampling ($n = 180$) was used to collect data on tree and soil carbon in disturbed and undisturbed mangroves. The impact of future climate on the carbon stock were modelled using the MIROC6 future climate model under SSP245 and SSP585 climate scenarios. Results showed that tree carbon stock (Mg.ha^{-1}) in site 1017 was 2.79 time higher in undisturbed sites (164.9 ± 8.19) than disturbed sites (59.14 ± 9.06), while in site 1018, it was 4.92 time higher in undisturbed sites (158.08 ± 12.28) than disturbed sites (32.14 ± 5.74). However, soil carbon stock was 1.12 and 1.25 times higher in undisturbed sites than disturbed sites in Ramsar sites 1017 and 1018, respectively. Future climate is predicted to decrease high carbon stock class by 2050 (4–8%) and 2080 (10–12%) under the two scenarios, but more so for SSP585 than for SSP245. At site 1017, future climate would cause a slight reduction (7.6%) compared to site 1018 where a higher reduction (52.6%) would be observed. Mangroves planting could help mitigating the predicted impact of future climate on carbon loss.

Keywords: Mangrove, Carbon, Conservation, Random Forest, Climate change, Ramsar site

Current knowledge and future prospects of African plants providing natural dyes: a systematic review

Wouyou H.G., Avocèvou-Ayisso C., Idohou R., Assogbadjo C.S., Houndonougbo J.S.H., Assogbadjo A.E.

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Natural plant dyes are essential products of biodiversity, providing numerous benefits to humanity. However further research is needed to ensure the conservation of dye-producing plants for future use. This systematic review aims to explore the existing knowledge on natural plant dyes, identify critical knowledge gaps and suggest future research directions for improved utilisation and conservation of these species. Seven online search engines, including Web of Science, ResearchGate, ScienceDirect, Research4Life, Google Scholar, PubMed and African Journals Online, were used to gather relevant literature following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. A total of 632 publications were examined, of which 112 were finally selected based on the inclusion criteria. The results showed a peak in publications in 2024, with eighteen articles published that year. Geographically, the largest number of studies focused on West Africa (n = 68), followed by East Africa (n = 23), North Africa (n = 13), Southern Africa (n = 5), and Central Africa (n = 3). Notably, Nigeria accounted for 44.6% of all studies reviewed, followed by Ghana and Ethiopia with 7.1%. A total of 555 species were identified as natural dye-producing plants, mainly used in textiles, traditional practices, cosmetics, food and dye solar cell. However, an analysis of research limitations revealed significant knowledge gaps in plant biodiversity, spatial distribution, climate modelling, ecosystem services, physico-chemical properties, and economic valuation which are essential for the sustainable valorisation and conservation of natural dye-producing plant species in Africa.

Keywords: Colouring plants, Natural colouring, Natural plant dyes, Systematic review, Conservation, Africa

Impacts of land-use change on carbon storage and sequestration in forest ecosystems in Benin

Ahononga F.C., Sonounameto R.C., Akabassi G.C., Gouwakinnou G.N., Biaou S., Biaou S.S.H.

Discover Applied Sciences, 7:1019

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Modeling the impacts of land-use change has become a critical concern in developing strategies to mitigate climate change. This study aims to assess the impact of land-use change on carbon flux. To simulate land-use changes by 2035, SPOT satellite images from 1995, 2005, and 2015 interpreted visually were integrated into the MOLUSCE module, which combines cellular automata and artificial neural network algorithms. These images, coupled with default carbon values, served as the basis within the InVEST model to estimate carbon storage over time. Results indicate that natural formations have been reduced in favor of agricultural land and settlements, with a carbon loss between 12.79 and 14.53% from 2005 to 2015. If this trend continues, an additional 5% carbon loss could occur between 2015 and 2035, highlighting that the destruction of natural formations would disrupt the carbon cycle and contribute to climate variability. In Toucountouna, projections indicate that the total estimated carbon stock in natural formations will decrease to 4,007,320.67 tons by 2035 if no action is taken. In Matéri, it is expected to decline to 292,256.58 tons. In Ségbana, the net loss is projected to reach 5,590,827.33 tons by 2035. Similarly, in Dassa-Zoumé, Ouaké, and Parakou, the estimated net losses by 2035 are 202,936 tons, 379,165.76 tons, and 841,667.1 tons, respectively. It appears important to implement effective land-use planning to restore forest ecosystem functions.

Keywords: Climate change, Land-use dynamics, InVEST model, MOLUSCE

Quantifying the Diversity of Normative Positions in Conservation Sciences

Gbedomon R.C., Salako K.V., Delorme D., Schlaepfer M.A.

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What elements of nature do people involved in conservation projects seek to protect, and why? How do they identify and relate to nature? Answers to such fundamental questions are shaped by normative assumptions that can result in distinct conservation strategies and practices. Despite their importance, normative assumptions are rarely explicitly stated in conservation sciences, possibly because an epistemology of modern science suggests that normative backgrounds are not relevant to the production of objective knowledge, or because researchers and practitioners are unaware of the diversity of positions that exist. Using a combination of qualitative and quantitative methods, we created a catalogue of existing normative positions in conservation literature and described their key characteristics. We described 72 distinctive normative positions about human–nature relationships. Each position was characterized by unique combinations of value-states belonging to one or more of the following five dimensions: ontology (the positionality of human with respect to nature), axiology (value systems and ethical frameworks), pragmatism (extent of human interventions), epistemology (knowledge sources), and agency (agents of change). We then scored each position in terms of its alignment (support, opposition, or neutrality) with respect to all value-states within each dimension. A fuzzy correspondence analysis revealed that the field of conservation is heterogeneous beyond the conventional gradient of intrinsic–instrumental–relational values. The frequency and circumstances under

which stakeholders adopt different normative positions are unknown, but the list of dimensions and associated values provided in this study may serve as a checklist for scoping this diversity. Consideration of values stemming from alternative normative positions may help broaden support for conservation actions.

Keywords: worldviews; biodiversity; conservation; values; normativity

Mat making from *Cyperus articulatus* in mangrove areas: a value chain analysis and economic insights in Benin (West Africa)

Gnansounou S.C., Salako K.V., Bonou A., Gbedomon R.C., Denon L., Assogbadjo A.E., Glèlè Kakaï R.

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Coastal zones offer more than fishery and wood. They also harbour overlooked resources vital to economic and social development. This study highlights *Cyperus articulatus*, a plant species thriving in Benin's mangrove areas and mainly used for artisanal mat-making, a product essential to millions across West Africa. The main aim was to analyse the value chain and the economic performance of the species' mat making sector. More specifically, the study used the case of the "la Bouche du Roy" protected area to map the value chain of the species' mat making sector and assess its economic performance, as well as key factors that influence its exploitation for appropriate decision-making. A mixed-method approach was employed, combining literature reviews, focus groups (n = 18), interviews (n = 20), and surveys (n = 602), while the data was collected from 2023 to 2024. Findings show that the collection of *C. articulatus* alone contributes 1.21 % to Benin's artisanal GDP. Among all sectors, only collection significantly reduces poverty, with collector profits surpassing the national poverty line. Annually, collectors

earn €2.6 million, substantially more than processors (€1.5 million), and mat sellers (€1.1 million), dried plant sellers (€880,402). Furthermore, geographical location (village), age, gender and household size influenced both the rate of exploitation, and the benefits derived from *C. articulatus*. As a predominantly women-led activity, *C. articulatus* exploitation presents a strong opportunity for empowering women. The study urges policymakers to implement conservation strategies to sustain this resource which strengthens the blue economy and enhances local livelihoods and resilience in coastal Benin.

Keywords: Mat making; Ecosystem services; Provisioning services; Mangroves; Blue economy.

North IUCN Red List of Ecosystems, Mangroves of the Gulf of Guinea -North

Salako K.V., McGregor S.G., Suárez E.L.

EcoEvoRxiv, 1-26

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Mangroves of the Gulf of Guinea - North is a regional ecosystem subgroup (level 4 unit of the IUCN Global Ecosystem Typology). It includes the marine ecoregions of Gulf of Guinea Central, Gulf of Guinea Upwelling, Gulf of Guinea West. The Gulf of Guinea - North mangrove province mapped extent in 2020 was 6961.2 km² across, representing 4.7% of the global mangrove area. The biota is characterized by 5 species of true mangroves. Although the province's mangroves provide several key ecosystem services they have undergone drastic reduction in their natural range. The mangroves of the Gulf of Guinea – North province are threatened by logging for fuel and charcoal production, conversion for agriculture or aquaculture, and industrial, urban, and tourism development. The mangrove net area change has been -2.9% since 1996. If this trend continues an overall change of -4.3% is projected over the next 50 years.

Furthermore, under a high sea level rise scenario (IPCC RCP 8.5) -9.5% of the Gulf of Guinea - North mangroves would be submerged by 2060. Moreover, 2.8% of the province's mangrove ecosystem is undergoing degradation, with the potential to increase to 6.4% within a 50-year period, based on a vegetation index decay analysis. Overall, the Gulf of Guinea - North mangrove ecosystem is assessed as Least Concern (LC).

Keywords: Mangroves; Red List of ecosystems; ecosystem collapse; threats.

Leveraging mangroves to advance climate action in Africa: Zooming in on Nationally Determined Contributions (NDCs)

Ofori S.A., Hugé J., Gnansounou S.C., Ximenes A.C., Asante F., Bagbohouna M.K., Comte A., Longépée E., Lang'at K.S., Bandeira S.O., Omollo D., Onyena A.P., Sam K., Hamza A.J., Zeggaf Tahiri A., Daf D.S., Goudiaby K.D., Olatunji E.T., Colléty C., Padonou E.A., Dahdouh-Guebas F.

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Mangroves are vital for climate change adaptation and mitigation due to their efficient carbon sequestration and coastal protection roles providing often untapped opportunities for countries to enhance their national climate commitments (including the so-called Nationally Determined Contributions) under the Paris Agreement adopted at the United Nations Framework Convention on Climate Change (UNFCCC) COP21 in 2015. In Africa, several countries possess mangroves and have signed the Paris Agreement, however, the level of integration of mangrove actions into the Nationally Determined Contributions (NDCs) has not been adequately explored. Using a systematic review methodology, 33 African countries possessing

mangroves were selected and their NDCs were reviewed, scored, and ranked to assess their level of integration of mangrove ecosystems into their NDCs. Countries like Equatorial Guinea, Nigeria, Senegal, and Sudan demonstrate commendable progress and leadership in integrating mangroves within their NDCs. However, gaps in budgetary commitments, spatial planning, and temporal specificity for mangrove actions among a majority of the countries hinder broader mangrove inclusion. The study also revealed a disconnect between research outputs and policy frameworks, where countries with increased mangrove research output in Africa failed to integrate mangrove actions into their NDCs. To increase African countries' resilience to climate risks and contributions to global climate goals, there is a need to increase effective collaboration between mangrove researchers, local communities, and policymakers in mangrove-possessing countries. This will bolster public education on mangroves and their inclusion of mangrove actions in their NDCs, ultimately enhancing the implementation of mangrove actions on the ground.

Keywords: Mangrove-possessing countries; Restoration; Conservation; Climate action; Mitigation; Adaptation.

Socio-cultural Factors Affecting Traditional Knowledge and the Cultural Significance of the Aromatic and Medicinal Plant, *Boswellia dalzielii* Hutch., in Burkina Faso

Sabo P., Tiétiambou F.R.S., Guindé H.T., Salako K.V., Johnson S., DeCarlo A., Mensah S., Glèlè Kakai R., Ouédraogo A.

Human Ecology, 53(3), 627-638

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The medicinal plant *Boswellia dalzielii* is well known and widely used by local communities in West Africa. However,

detailed information about this knowledge and its distribution among local people remains poorly documented. We assessed traditional knowledge (TK) regarding the use of *B. dalzielii* in communities in Burkina Faso. We conducted 160 semi-structured interviews and analyzed the patterns of specific uses and use categories based on the average number of reports per informant, use value (UV), and cultural importance index (CI). Results revealed 42 specific uses of *B. dalzielii*, grouped into five use categories: medicine, food, construction, cultural uses, and firewood. The bark was the most frequently cited part. UV varied significantly across ethnic groups and age categories, and factors such as gender and education level also significantly influenced the species' CI. Informants from the Mossi ethnic group and older informants demonstrated greater knowledge of the species.

Keywords: *Boswellia dalzielii* Hutch.; Burkina Faso; Frankincense tree; Human-plant Interaction.

Integrating phenotypic and genetic diversity, and species distribution modeling to set long-term conservation strategies for the endangered *Azelia africana* in Benin (West Africa)

Adjacou D.M., Idohou R., Yaoitcha A.S., Ayena J.K.I., Houehanou T.D., Gouwakinnou G.N.

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Azelia africana is one of the most threatened multipurpose species in sub-Saharan Africa. Understanding its potentially suitable habitats, coupled with its phenotypic and genetic diversity, is valuable for establishing sustainable and efficient conservation strategies for the species. This study combines phenotypic and genetic data with best-fit habitat models to identify conservation opportunities for *A. africana* across Benin.

Natural populations were sampled for phenotypic and genetic diversity. Occurrence data were collected in the field and supplemented with available data from GBIF. Current and future climate data under two Shared Socioeconomic Pathways (SSP2-4.5 and SSP5-8.5) were used to model the current and potential future distribution of the species using MaxEnt. The results showed a large natural variation in phenotypic diversity, with populations from the Sudano-Guinean zone exhibiting intermediate diversity ($H' = 0.45$), while those from the Guinean and Sudanian zones exhibited high levels of diversity ($H' > 0.60$). Currently, 55.40 % of the country was predicted to be potentially suitable for the conservation of *A. africana*. Under the SSP5-8.5 and SSP2-4.5 scenarios, a significant increase respective of 70.27 % and 68.85 % in suitable habitat is predicted by 2041–2060. Nevertheless, which will negatively affect both phenotypic and genetic diversity. However, individuals from the Sudano-Guinean subgroup are the most vulnerable to future climate conditions. This integrated approach not only helps to identify potential conservation areas but also reveals a crucial interplay in the phenotypic diversity and genetic dynamics of the species.

Keywords: *Afzelia Africana*, Genetic diversity, Phenotypic diversity, Climate change, Conservation, West Africa

Drought and flood hazards in inland valleys of Benin: severities, adaptation strategies and associated factors across the Sudano-Guinean and Guinean zones

Akodekou A.D., Dossou-Yovo E.R., Salako K.V., Gnansounou S.C., Diarra S.T., Nehren U., Glèlè Kakaï R.

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Inland valleys (IVs) are vital socio-ecological systems in Sub-Saharan Africa and are crucial for agriculture and ecosystem services. However, they are susceptible to drought and flooding and require adaptation strategies informed by robust spatiotemporal analyses of hazards. This study (i) assesses the spatial and temporal distribution and severity of drought and wet conditions; (ii) identify key climatic and biophysical factors associated with these events; and (iii) determine the socio-economic and environmental factors associated with farmers adaptation responses in Benin. Biophysical, climate (1991–2021) and socio-economic data were collected in 68 IVs distributed in Benin's Guinean and Sudano-Guinean climate zones. Results showed that the years 2001, 2002, and 2016 were classified as extreme drought years across all IVs, while 2008, 2009, and 2019 experienced extreme wetness. Drought, occurring in 35 % of the total IVs, was more frequent in the Sudano-Guinean zone and mainly characterised by soil organic carbon, standardised precipitation evapotranspiration index (SPEI), and sand content. Wet, affecting 30 % of the total IVs, was more frequent in the Guinean zone and was linked to average annual rainfall, sand content, and SPEI. Farmers responded to drought hazards by adopting organic farming (58 %), implementing irrigation (47 %) and adjusting cropping seasons (85 %). For extreme wet and flood hazards, farmers responded with changes in the cultivation areas (76 %), agroforestry and use of straw and fallow (64 %), and adjustments in cropping seasons and areas (84 %). These adaptation strategies were influenced by market access, access to extension services, and infrastructures. The study underscores the need for enhancing monitoring and early warning systems that integrate climate, soil, and socio-economic factors to better detect and respond to drought and flood risks.

Keywords: Inland valleys; Climatic hazards; Hazard adaptation strategies; Food security; Sub-Saharan Africa.

Cocoa agroforestry and biodiversity: identification of priority species for sustainable management in Côte d'Ivoire

Assalé A.A.Y., Hounsou-Dindin G., Konan G.D., Donou Hounsodé T.M., Salako K.V., Barima Y.S.S., Glèlè Kakaï R.

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Woody species in cocoa-based agroforestry systems, survivors of deforestation and the degradation of natural ecosystems, are suffering the negative impacts of climate change. This study aims to define conservation priorities for these species, which are essential to the well-being of local populations for the sustainability of cocoa farming in Côte d'Ivoire. Ethnobotanical surveys were conducted among 50 farmers selected across five villages in the Bonon region, the second largest cocoa-producing area in Côte d'Ivoire. The species used by the communities were sourced from a literature review, while floristic inventories in cocoa agroecosystems were used to assess their availability. This methodological approach revealed the diversity of species providing provisioning services to populations, while analysing their socioeconomic value and availability according to prioritization criteria. These criteria, integrated into a data matrix and processed by a Principal Component Analysis (PCA), facilitated the prioritization of woody species to be conserved. In total, 53 woody species are used by local people to meet their daily needs. However, the species with the highest socioeconomic values are also the least available. Among them, ten have been identified as priorities for conservation namely: *Nesogordonia papaverifera*, *Ricinodendron heudelotii*, *Milicia excelsa*, *Sterculia tragacantha*, *Holarrhena floribunda*, *Alstonia boonei*, *Antiaris toxicaria*, *Celtis zenkeri*, *Cordia*

platythyrsa and *Vitellaria paradoxa*. These species require special attention to ensure the resilience and sustainability of cocoa agroforestry systems in Côte d'Ivoire.

Keywords: Climate change; Agroforestry; Ecosystem services; Biodiversity; Sustainable management.

A review of *Momordica* species in Africa (Cucurbitaceae): current knowledge and perspectives for sustainable management

Assogbadjo C.S., Avocèvou-Ayisso C., Idohou R., Wouyou H.G., Houndonougbo J.S.H., Hounsou-Dindin G., Assogbadjo A.E.

Ethnobotany Research and Applications, 30:73

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Background: African Indigenous Vegetables (AIVs), particularly species of the genus *Momordica*, are crucial for West African communities, offering nutritious leaves, fruits, and seeds used both as food and traditional medicine. Earlier publications emphasized the significance of the genus *Momordica*, focusing on pharmacology, traditional uses, and biochemical components. However, current knowledge and research on sustainable management policies remain limited. This study presents a comprehensive systematic review of the past three decades, highlighting publication trends and key insights on the conservation ecology and domestication of *Momordica* species in Africa. Methods: The search was conducted in four academic databases and covered peer-reviewed literature from 1993 to 2023. This systematic review initially identified 1,480 potentially relevant publications. Through a sequential screening process, beginning with evaluating titles, keywords, and abstracts, followed by a full-text assessment based on predefined inclusion criteria, 128 studies (8.6%) were

ultimately selected for in-depth analysis. Results: A systematic analysis of the literature reveals that research on *Momordica* species has been geographically uneven across Africa. Most studies have been concentrated in West Africa (n = 89). *Momordica charantia* L. (n = 59), *Momordica balsamina* L. (n = 20), and *Momordica foetida* Schumach. (n = 18) emerged as the most frequently investigated species. Despite growing interest, the systematic review reveals significant research gaps, especially regarding ecosystem services, genetic diversity, and the conservation status of *Momordica* species across Africa. Conclusion: Addressing these gaps could facilitate more informed decision-making and promote sustainable strategies for the ongoing domestication of these species in Africa.

Keywords: African Indigenous Vegetables, genus *Momordica*, Ethnobotany, Conservation biology, Domestication.

Use patterns and distribution of indigenous knowledge on three *Momordica* species in Benin, West Africa

Assogbadjo C.S., Avocèvou-Ayisso C., Wouyou H.G., Idohou R., Agontinglo E.L.T., Balley M.W., Aiya C.C., Assogbadjo A.E.

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The genus *Momordica* plays a crucial role in African livelihoods, thanks to its medicinal applications, nutritional value, and importance in traditional practices and knowledge transmission. This study focuses on *Momordica charantia* L., *Momordica balsamina* L., and *Momordica cissoides* Planch. ex Benth., to explore their traditional uses and examine the socio-linguistic factors that may influence their utilization in the Beninese context. Through ethnobotanical surveys (712 respondents, 18 socio-linguistic groups,

nine phytodistricts), we identified 16 uses, predominantly medicinal, with *M. charantia* exhibiting the highest diversity, notably in treating measles (Relative Frequency of Citation = 81.05 %) and chickenpox (RFC = 74.29 %), while *M. balsamina* and *M. cissoides* were linked to malaria. Analysis of variance (ANOVA) indicated significant gender differences in knowledge for *M. charantia* ($F = 14.62$, $p < 0.001$) and *M. cissoides* ($F = 9.87$, $p < 0.001$). Correspondence Analysis (CA) further highlighted distinct cultural preferences in the usage of plant part usage across the three *Momordica* species. For *M. charantia*, Dim1 (explaining 73.7 % of variance) showed strong associations with fruit ($r = 0.91$) and root usage ($r = 0.87$). Socio-linguistic groups such as the Mahi, Holi, and Otammari predominantly used stems and leaves, while the Lokpa, Fon, and Adja favored fruits, and the Yom and Peulh prioritized roots. In *M. cissoides*, Dim1 (77.4 %) was similarly linked to stems/leaves and roots ($r = 0.88$ each). For *M. balsamina*, Dim1 (69.8 %) showed strong associations with stems/leaves ($r = 0.84$) and fruit ($r = 0.91$), underscoring the role of socio-linguistic identity in shaping use patterns. Sankey diagrams and ethnobotanical indices (RFC, UV, CMU) confirmed medicinal dominance, with *M. charantia* most cited. The Botanical Ethnoknowledge Index (BEI) showed significant knowledge disparities among Benin's cultural groups, with the Adja (BEI = 0.95) demonstrating the highest traditional expertise, highlighting sociocultural influences on *Momordica* use and conservation needs. Findings underscore the nexus between cultural identity and plant use, advocating interdisciplinary strategies (ethnobotany, conservation biology, participatory approaches) to safeguard traditional knowledge and ensure *Momordica* species' resilience.

Keywords: Benin, Conservation, Ethnobotany, Socio-cultural factors, Wild edible plants

Ensemble modelling reveals spiny monkey orange (*Strychnos spinosa* Lam.) as a vulnerable wild edible fruit tree in West Africa

Avakoudjo H.G.G., Vodounnon M.E.J., Idohou R., Coulibaly A., Assogbadjo A.E.

Ecology, and Landscapes, 10(1), 261-276

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This study aimed at modelling the historical distribution and assessing the potential impacts of future climate on spiny monkey orange (*Strychnos spinosa* Lam.) population across West Africa using the Shared Socio-economic Pathways (SSP 245 and SSP 585) scenarios at the 2041–2060- and 2081–2100-time horizons. Bioclimatic and soil variables were used at a resolution of 30 arcseconds with 588 occurrence records analysed using five algorithms (Random Forest (RF), Maximum Entropy (MaxEnt), Support Vector Machine (SVM), Boosted Regression Trees, and Generalized Linear Model (GLM)) and four global climate models (CanESM5, CNRM-CM6-1, HadGEM3-GC31-LL, and MIROC6). The Models' performance was evaluated using the Area under the Curve (AUC), True Skill Statistic (TSS), Correlation coefficient (COR), and the Deviance. The most efficient algorithm (RF) was employed for the modelling, and the resulting maps were overlaid on the existing protected area network. The distribution modelling under future climate revealed an increase in the high and moderate suitability areas for *S. spinosa* at 2041–2060 and 2081–2100 horizons. Based on the results, Circa-situm conservation and ex-situ conservation strategy should be encouraged in addition to protected area network (PAN).

Keywords: Climate change; conservation; potential distribution; *Strychnos spinosa*

Bayesian Modeling of Geostatistical Survival Data With Misaligned Covariates: A Simulation-Based Study of Malaria Risk in Gabon

Beh Mba R., Glèlè Kakai R.

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Malaria remains a leading cause of morbidity and mortality in sub-Saharan Africa, with spatial heterogeneity in transmission posing significant challenges to effective disease control. Accurate estimation of survival risk in relation to local malaria prevalence is often hampered by spatial misalignment, a scenario in which infection covariates and health outcomes are measured at different geographic locations. This study addresses this critical issue by developing a Bayesian hierarchical framework that jointly models malaria infection risk and survival outcomes under spatial misalignment. We employ a two-stage approach: First, malaria prevalence is modeled geostatistically using a spatial binomial model with Gaussian random effects; second, the predicted infection risk and its associated uncertainty are incorporated into a Bayesian accelerated failure time (AFT) survival model. Through a simulation study calibrated using empirical malaria survey data from Gabon, we evaluated the performance of this joint model under varying degrees of spatial misalignment, censoring, and spatial resolution. Results demonstrate that ignoring spatial misalignment leads to biased effect estimates and poor predictive accuracy, particularly in high-risk zones. The proposed Bayesian model consistently outperforms competing methods in terms of parameter recovery, credible interval coverage, and spatial prediction of mortality risk. It also proves robust to high levels of right-censoring and covariate prediction error. By integrating spatial processes and uncertainty propagation, our framework enables more reliable identification of high-risk regions for targeted intervention, offering a robust tool for malaria risk mapping in settings with sparse or misaligned data.

Keywords: accelerated failure time (AFT); Bayesian hierarchical model; Gabon; geostatistical survival analysis; malaria modeling; spatial misalignment

Variability in *Pterocarpus erinaceus* Poir. Traits Along an Aridity Gradient Provides Insights Into Its Adaptation to Dry Environmental Conditions

Biaou S., Salako K.V., Noulèkoun F., Sodedji A.F., Hounwanou G.B., Houehanou T.D., Ouinsavi C., Gouwakinnou G.N.

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Understanding species adaptation to environmental changes is crucial to guide conservation and habitat restoration. This study examined variability in *Pterocarpus erinaceus* Poir. traits along an environmental gradient in Benin, ranging from humid (Guinean), subhumid (Sudano-Guinean) to semi-arid (Sudanian) zones. Data on fourteen morphological and functional traits were collected from 120 trees along this gradient. Canonical discriminant analysis was used to identify traits that differentiate each climate zone, while redundancy analysis was employed to explore relationships between discriminative traits and environmental variables. Both univariate and multivariate (MVPi) plasticity indices were further computed to assess trait variability. Petiolule length (PeL), petiole length (PEL), diameter at breast height (DBH), number of branches (NB), and leaf mass per area (LMA) were the most discriminative traits. PeL, PEL, and LMA significantly decreased from arid (0.7 ± 0.15 cm, 4.5 ± 0.67 cm, 69.44 ± 15.17 g/m², respectively) to humid zones (0.4 ± 0.08 cm, 3.8 ± 0.48 cm, 40.9 ± 10.90 g/m², respectively), whereas NB declined from humid (11.7 ± 4.68) to arid zones (6.68 ± 1.64). Temperature, rainfall, and aridity positively influenced PEL and PeL but negatively influenced NB. DBH, NB, and LMA were negatively related to soil type. Substantial plasticity (0.45–0.50) was

observed at individual trait level. When aggregated over all traits (MVPi), trait plasticity was slightly higher for SGZ vs. SZ and SZ vs. GZ compared to that for SGZ vs. GZ. Our findings highlight the function trade-offs underlying the growth and local adaptation of the species across the climatic zones. These insights underscore the importance of conserving the species' subpopulation within their respective ecological zones. Future research should explore the species' genetic diversity and adaptation mechanisms to enhance its conservation strategies.

Keywords: adaptative strategy; Benin; conservation; sustainable management; West-Africa

A global synthesis of research on plant local adaptation to climate change: plant diversity, methodological approaches and future roadmap

Biaou S., Noulèkoun F., Salako K.V., Houehanou T.D., Ouinsavi C., Gouwakinnou G.N.

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Local adaptation studies provide a critical framework for understanding how environmental factors drive the evolution of plant traits, especially in the context of climate change. Despite the existing evidence on local adaptation of plant species to climate change (LAPCC), knowledge on the diversity of studied species, their life forms, and conservation status as well as appropriateness of methods remains limited, thereby hindering the design of effective conservation strategies. This study aims to synthesize trends in scientific production on LAPCC with emphasis on the studied species and analytical methods, identify research gaps in LAPCC studies, and propose a roadmap to address these gaps. From an initial set of 2,292 articles identified with relevant keywords in three databases, 213 were fully analyzed. A

temporal analysis showed a rapid and significant increase in the number of articles between 2000 and 2024. Most studies were conducted in America (49.29%) and a few originated from Africa (3.75%). The studies have predominantly employed quantitative genetics (43.52%), followed by landscape genomics (21.76%) and population genomics (14.35%). Most studies focused on trees (55.09%) and herbaceous (34.75%) plants, while research on shrubs (10.19%) was underrepresented. LAPCC studies mainly considered well-known and low-risk species, thereby overlooking threatened species. Our findings highlight several gaps, including low contribution of Africa to the LAPCC literature, limited focus on endangered species, and lack of an integrated methodological framework. Consequently, we proposed a three-step roadmap for future LAPCC studies: (1) improving the representation of understudied species and geographical areas, (2) fostering the study of species with high conservation needs, and (3) adopting a more integrated analytical approach combining several methods. Overall, our review offers a framework for improving LAPCC research and guiding biodiversity conservation efforts globally and effectively.

Keywords: Ecological genetics; biodiversity conservation; divergent selection; genetic differentiation; intraspecific variation; threatened species.

Ecosystem services provided by *Ricinodendron heudelotii* (Baill.) Pierre ex Heckel in Benin: Local perception and associated factors

Gandji M.R.M., Salako K.V., Hounsou-Dindin G., Glèlè Kakai R., Assogbadjo A.E.

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Ricinodendron heudelotii is a multipurpose wild oil tree native to Africa, including Benin, where it is less abundant

compared to common NTFPs-providing species. Understanding socio-demographic and geographic factors associated with local perceptions of the ecosystem services (ES) it provides can offer valuable insights to better guide its valorisation and conservation. In this study, face-to-face interviews were conducted across the two biogeographical zones (Soudano-Guinean and Guineo-Congolian) where it is found in Benin to investigate local knowledge of its ecosystem services and associated factors. The diversity and perceived importance of ecosystem services were analysed using quantitative ethnobotanical indices. Results showed that provisioning services were mostly reported (58.50 %) in the Soudano-Guinean zone while cultural services (40.90 %) were mostly mentioned in the Guineo-Congolian population. In the Guineo-Congolian zone, the stem of its adult individuals is mainly used to make the "Guèlèdè mask" and the tam-tam (a kind of drum), which are used during local ceremonies. In both zones, the leaves and bark of the tree are widely used for medicinal purposes, primarily malaria, fever, and childbirth facilitation. Human food uses were only mentioned in the Sudano-Guinean zone where leaves are used as ingredient in Ocra sauce. Gender and residential status were associated to the knowledge of provisioning services, while age was the only factor associated with the knowledge of cultural services. These results show that the species is better known and valued by adults, particularly in the Guineo-Congolian zone. Raising local awareness of the species' ecological and economic importance aims to promote the sustainable use of its resources, foster its integration into agroforestry systems and reduce pressure on natural populations, thereby supporting its long-term conservation and sustainability.

Keywords: Akpi; Human well-being; Cultural keystone species; Guèlèdè dance; UNESCO; Africa

Synergies between legal frameworks and traditional rules, and their potential for enhancing the social-ecological resilience of mangroves

Gnansounou S.C., Salako K.V., Pellowe K.E., Diallo K., Glèlè Kakaï R., Kestemont P., Henry S.

Ocean & Coastal Management, 271, 107950

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Although formal institutions, particularly legal instruments which protect coastal ecosystems exist in many coastal countries, their contribution to enhancing the social-ecological resilience of mangroves has been limitedly explored. This study investigated how the synergies between legal instruments and local deities existing in coastal countries can contribute to enhancing the resilience of mangroves, using Benin Republic (West Africa) as a case study. The study employed seven principles of resilience derived from the literature to assess the existence, application, and respect of the legal framework that enhances the resilience of mangroves in Benin. Various data were collected through documents review (18 laws comprising 2727 articles), in-depth interviews (n = 18), focus groups discussions (n = 9) and drone-based field observations. Out of the 2727 articles reviewed, 93 articles summarized into 20 provisions were found to potentially enhance the resilience of mangroves, as they aligned with the considered principles of resilience. Although decrees, orders and law enforcement agencies exist to ensure the application of these provisions, challenges related to inadequate sensitization, insufficient resources, weak collaboration among institutions and land-related issues compromise their enforcement locally. Interestingly, the introduction of local deities in coastal areas, particularly for mangrove conservation facilitates the respect of some key provisions, notably

the ban on mangrove wood cutting. This study identifies legal instruments as one of the important tools that can be used to enhance the social-ecological resilience of mangroves and calls for the incorporation of traditional beliefs in their effective enforcement to foster compliance and promote the sustainability of the ecosystem.

Keywords: Mangrove governance; Social-ecological systems; Social-ecological resilience; Local deities; Traditional beliefs; Benin

Utilitarian diversity of *Senna occidentalis* in Benin, West Africa: Ethnobotanical insights and sustainable management

Idohou R., Wouyou H.G., Agbangba E., Dossou A.

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Background: *Senna occidentalis* (L.) Link is a medicinal plant whose therapeutic properties have been widely appreciated in medicinal preparations throughout the world. This study investigates the indigenous knowledge and use of *S. occidentalis* throughout Benin. Methods: The study was carried out in nine communes of Benin. From September to November 2023, semi-structured interviews were conducted in 72 villages, involving 195 respondents from 14 different sociolinguistic groups. Cramer's test was used to determine the degree of relationship between socio-linguistic groups and the forms and parts of the plant used. In addition, a Correspondence Analysis (CA) was performed to examine variations in species consensus values. Results: Our results showed that the species is primarily used for medicinal purposes (93.57%), with smaller proportions allocated to food (3.21%) and medico-romantic applications (3.21%). The uses of the species varied with socio-

linguistic affiliation. Decoction (71.88%), infusion (7.63%), toothpick (6.42%) and trituration (6.02%) were the forms mainly used by the local population. The leaves (71.08%) were the most commonly used part of the plant. Roots (20.08%) and seeds (8.83%) were used, but to a lesser extent. In addition, leaves and roots were mainly used parts of the species to treat malaria and typhoid fever, while seeds were used for constipation. Conclusions: These results demonstrate the medicinal importance of *S. occidentalis* in Benin and suggest the need for priority actions for the sustainable management and use of the species. Further research on the medicinal components of different parts of the plant could aid its promotion and valorisation.

Keywords: Ethnobotany; Asteraceae; Indigenous communities; Human diseases; Herbal medicine

Solanum wild relative species indicate varying ecological resilience to climate change in Benin (West Africa)

Kégbé A.M., Idohou R., Dieng B., Agounde G., Egeru A., Noba K., Assogbadjo A.E.

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Crop wild relatives are rich reservoirs of valuable genes for improving crop yields, but they have long been underestimated and neglected. Unfortunately, these resources are severely threatened in their natural habitats due to increasing stress caused by climate change and human disturbance. Recently, these wild species began receiving increasing attention for their effective inventory and sustainable conservation and use for the benefit of humanity. This study investigated the current distribution and forecasted the potential future climate change impact on ten *Solanum* wild relative species in Benin, assessed the effectiveness of protected areas in maintaining viable populations, and evaluated their

conservation status using the International Union for Conservation of Nature Categories and Criteria. We used species distribution models under two socioeconomic pathways SSP370 and SSP585 projecting species ranges for the 2055 and 2085-time horizons. The models demonstrated high accuracy with an average value of the Area Under the Curve and True Skill Statistic of 0.89 and 0.74, respectively. The most suitable areas were located in the Sudano-Guinean and Guineo-Congolian zones of Benin. Furthermore, a significant proportion of these suitable areas is projected to become unsuitable for most wild *Solanum* species. Surprisingly, most of the identified hotspots were poorly represented within the existing protected area network, which appears insufficient to provide long-term refugia for the species. Nevertheless, new suitable areas were identified outside the current protected zones. Coordinated efforts are urgently needed to sustainably manage the populations of target species to enhance their future persistence in Benin.

Keywords: Crop wild relatives; climate change; protected area networks; *Solanum*; species distribution modelling

Vulnerability of agrosystems to climate change in the surrounding areas of Pendjari National Park of Benin

Kouhouenou V., Hounsou-Dindin G., Tekla O., Tchekoté H.

Discover Agriculture, 3(1), 259

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Understanding the vulnerability of agrosystems to climate change is vital for farmers to adapt effectively. This study evaluates the vulnerability of agrosystems around Pendjari National Park (PNP) to guide effective agricultural systems restoration strategies. Rainfall trends from 1980 to 2021 were analysed using daily precipitation data from the Tanguieta weather station. A floristic inventory was

conducted along the Tanguiéta-Batia and Tanguiéta-Porga corridors using the linear transect method to identify agrosystems based on tree density per hectare. The vulnerability of the most prevalent agrosystems was assessed through surveys of 318 households using individual and semi-structured interviews. Data analysis included descriptive statistics and correspondence analysis on tree and crop distributions using R software. Vulnerability was measured using three indices: exposure, sensitivity, and adaptive capacity. Results showed a general decline in rainfall over the study period, with alternating years of drought and surplus. Nine agrosystems comprising 28 woody species and 8 crop species were identified, predominantly featuring *Vitellaria paradoxa* and *Parkia biglobosa*. Both systems are vulnerable to climate change, but *V. paradoxa* agrosystems (Vulnerability Index = 1.36) are less vulnerable than those of *P. biglobosa* (Vulnerability Index = 3.27). This study establishes a basis for further research on the food, economic, and agronomic benefits of trees in these agrosystems. It recommends that policymakers and farmers prioritize *V. paradoxa* agrosystems, promoting policies that support climate adaptation, resilience, and sustainable resource use. Local communities are encouraged to adopt sustainable agricultural practices to ensure long-term food and economic security.

Keywords: Adaptation; *Parkia biglobosa*; Rainfall; Resilience; Vulnerability index; *Vitellaria paradoxa*

Current Knowledge and Research Perspectives on Bryophytes in West Africa

Kpetikou C.G., Agounde G., Dassou G.H., Salako K.V., Tossou G.M., Hedderson T.

Diversity, 17(12), 807

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Bryophytes are non-vascular plants comprising mosses, liverworts and hornworts. In West Africa, they are one of the least investigated components of biodiversity, receiving far less attention than vascular plants. This systematic review synthesizes the current knowledge on bryophytes in West Africa and identifies gaps and future prospects for advancing bryophytes research. Since the earliest explorations in the 18th century, bryophyte research in West Africa has remained poorly developed, with a noticeable bias toward certain countries over other countries. Over the past four decades, bryophyte research and the number of recorded species have increased. To date, 1175 bryophyte species and infraspecific taxa, representing 320 genera and 120 families, were recorded in the region, of which 6.47% are endemic. This documented diversity surely does not represent the full flora of the region: many species are evidently still undescribed. Another major constraint on advancing knowledge is the scarcity of specialists in the region and the lack of sustained scientific interest and academic focus in the taxonomic group. A priority for advancing knowledge on bryophytes in West Africa is to strengthen taxonomic research to document biodiversity, alongside comprehensive studies on bryophyte diversity and distribution across regions.

Keywords: bryophytes; research gaps; species diversity; West Africa

Legacy effects of fire on tree diversity, structure and aboveground carbon in tropical semi-arid naturally assembled communities

Mensah S., Noulèkoun F., Salako K.V., Dimobe K., Sheppard J., Assogbadjo A.E., Glèlè Kakaï R., Seifert T.

Ecological Informatics, 92, 103487

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Seasonal fires are integral to the ecological functioning of tropical savannas; however,

increasing fire frequency threatens the integrity of these ecosystems by reducing their productivity and the ecosystem services they support. The role of species population demography, functional traits and phylogenetic structure in regulating plant community responses to repeated fires is crucial in this context. Combining plot-based tree inventory data with two decades (2001–2021) of remotely sensed fire history across West African tree and shrub savannas, we examined climate-fire feedback, and assessed how multiple components of tree diversity – taxonomic, structural, functional and phylogenetic – as well as key stand characteristics, relate to fire frequency, climate variability, and aboveground tree carbon stock. Fire frequency was closely associated with rainfall and its seasonality, highlighting the role of prolonged dry spells in fuel load accumulation. Although repeated fires did not significantly impact tree diversity in any dimension, they were negatively related to both the density of the largest trees (top 5% by size) and aboveground carbon stock. Notably, plots that burned more than five times over two decades showed substantial declines in tree carbon storage. Among all measured variables, the density of the largest trees emerged as the strongest correlate of aboveground carbon, alongside species richness and phylogenetic diversity. However, it was the only variable consistently mediating the negative pathway between fire frequency and aboveground carbon. Our findings (i) show a convergence of multiple tree diversity dimensions in their response to frequent fires, pointing to the resilience of savanna tree diversity to repeated burning, potentially due to long-term adaptations of the local species pool, but also (ii) underscore the vulnerability of biomass accumulation and carbon storage to fire-induced demographic shifts. Increased fire frequency propelled by both climate change and human interactions in the surrounding agricultural lands would jeopardise the capacity of these plant communities to

maximize carbon storage, highlighting the need for fire management strategies that sustain ecosystem functions under future environmental pressures.

Keywords: Carbon stock; fire; functional traits; phylogeny; stand structure; West Africa; ecosystem functioning

Deep learning enables precision agriculture for sustainable chili pepper disease detection in Benin

Odounfa M.G.F., Hounmenou C.G., Salako K.V., Affokpon A., Glèlè Kakai R.

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Ensuring food security is a crucial priority for nations worldwide, but plant diseases significantly hinder this objective, through their impacts on agricultural productivity. Chili pepper (*Capsicum* spp.) is a major crop in West Africa including in Benin. However, its production is challenged by diseases such as anthracnose and Tomato Yellow Leaf Curl Virus (TYLCV) which severely impact its yields and farmer livelihoods. While traditional methods for disease detection and management have been commonly used, they are no longer sufficient to combat rising pest infestations and declining agricultural productivity. To tackle this issue, we built a comprehensive dataset of 213 images of anthracnose-affected leaves, 202 images of TYLCV-infected leaves, and 119 images of healthy leaves, collected under diverse environmental conditions in Benin. The study compared the performance of thirteen (13) deep learning models including among others YOLOv8, MobileNetV2, and DenseNet121 for the classification of chili diseases in Benin using transfer learning techniques to improve their accuracy, based on values close to one (1) of evaluation metrics such as Accuracy, Precision, Recall and F1-Score. Results show that YOLOv8 outperforms other models in detecting and localizing leaf diseases in real time. It

achieved a mean Average Precision (mAP@0.5) of 0.995 and mAP@0.5–0.95 of 0.941, demonstrating strong generalization. With precision and recall exceeding 99%, YOLOv8 proves highly reliable for agricultural applications. Among classification models, MobileNetV2 and DenseNet121 achieved 96.25% accuracy, confirming their effectiveness in disease classification. Our findings demonstrate that deep learning models, particularly YOLOv8, hold immense potential for real-time, automated detection of chili pepper diseases. Future research should focus on expanding datasets, integrating climatic variations, and improving disease severity assessment for enhanced agricultural sustainability.

Keywords: Deep learning; Real-time detection; Pepper diseases; Capsicum; Agricultural sustainability

Deep learning-based methods for predicting COVID-19: A critical review

Tinhoun F.S., Doumatè T.J., Glèlè Kakai R.L.
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The COVID-19 pandemic, caused by SARS-CoV-2 and first identified in Wuhan, China, disrupted human life worldwide. Numerous modelling studies have aimed to understand its dynamics. This systematic review analyses and summarizes deep learning-based techniques used to predict COVID-19 cases. A research approach is outlined to perform a systematic literature review, focusing on formulating research questions, defining search criteria, and extracting relevant data. In total, 102 papers were considered after meeting the inclusion and exclusion criteria. Regarding scaling methods, two were reported, with normalization being the most widely used (39.22%). Eight hyperparameter selection processes were reported, with grid search

(6.87%), Bayesian optimization (2.94%), and manual search (2.94%) being the most commonly applied. Regarding model validation strategies, split validation (91.2%) was the most commonly used. For COVID-19 prediction, findings revealed that long short-term memory networks were the most extensively used (48.31%). Other frequently used models included hybrid models, gated recurrent units, convolutional neural networks, recurrent neural networks, compartmental models enhanced with deep learning, multi-layer perceptrons, and deep neural networks. Regarding what was predicted, confirmed cases were the most frequently predicted (29.95%), followed by deaths, new cases, recoveries, epidemiological parameters, active cases, intensive care unit admissions, and hospitalizations. However, several papers failed to report valuable and anticipated information derived from deep learning models. Scaling methods were not reported in 57 articles (55.88%), and hyperparameter selection processes were only noted in 19.61% of the papers. Additionally, the software used was reported in only 29.41% of the studies. To ensure the reliability of COVID-19 predictions, researchers must explicitly document the conditions under which deep learning models perform optimally and identify biases that could affect predictions.

Keywords: machine learning; infectious diseases; optimization; systematic review

Digital Technology and the Crop Calendar for Efficient Agriculture in West Africa

Tognisse I.S., Degila J., Sounouvou M., Sodedji A.F., Salako K.V., Agbahoungba S., Agoyi E., Ahouansou M., Assogbadjo A.E.
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Crop planning is an important activity for players within the agricultural sector, involving the consideration of several parameters. However, with climate change, there have been significant changes that have meant that most farmers do not have a firm grasp of the agricultural calendar. There is also the inaccessibility of a precise crop calendar, which has consequences for agricultural productivity. This study presents a review of the literature on agrarian calendars. The aim is to understand what already exists in terms of research with a view to setting up a complete system that will enable universal access to agricultural calendars for populations such as those in West Africa based on digital technologies. To do this, we carried out a bibliometric review by extracting data from the Scopus database and then conducted a study of existing platforms providing free access to digital calendars for farmworkers with free access to digital calendars. Based on the results of these reviews, we proposed a complete digital system to provide farmers with agricultural calendars for efficient agriculture in West Africa.

Keywords: Crop calendar; digital; access; Agriculture

Cultural and socio-economic drivers of conservation and cultivation of the cola nut tree

Tokannou I.E., Sanogo S., Salako K.V., Hounkpèvi A., Dogbo S.F., Fandohan A.B.

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Cola nitida (Vent.) is an essential multipurpose tree in most West and Central African countries. In Benin, it is

threatened with extinction due to overexploitation and climate change. This study was carried out to contribute to the development of appropriate management strategies. Specifically, the study aimed to assess the impacts of socio-cultural, socio-demographic, and socio-economic factors on the local communities' decision to conserve and cultivate *C. nitida* in Benin. Semi-structured surveys were carried out with 518 respondents in the Guinean-Congolese zone of Benin, where it mostly occurs. In addition to the respondent's characteristics, data were collected on the number of *C. nitida* trees owned, the species' use value, and the informant's technical knowledge on the species' cultivation. Generalized linear models and piecewise Structural Equation Modeling (pSEM) were used to identify the main factors associated with the use value, the decision to conserve, and to cultivate *C. nitida*. The results indicated a positive relationship between the technical knowledge of the species production and *C. nitida* use value, indicating that higher technical knowledge is held by people who use more the species. Furthermore, respondents' age, gender, geographical location, and the species' use value were the main factors associated with the decision to conserve the species. The decision to cultivate the species is rather associated with the species' use value, the income generated from its exploitation, and the respondent's religion. Actions on gender equality and customized to sociocultural contexts are needed to ensure the sustainable management of the species in Benin.

Keywords: *Cola nitida*; Use value; Agrosystems; Cultural prohibitions; Market opportunities; Phytogeographical district



Natural regeneration of *Mimusops andongensis* monitored in a study of natural regeneration dynamic in the Lama forest reserve, Southern Benin.
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