Annual Report 2023

Laboratoire de Biomathématiques & d'Estimations Forestières

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Acknowledgements

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Abbreviations & acronyms

AGNES	:	African German Network of Excellence in Science
EDCTP	:	European and Developing Countries Clinical Trials Partnership ()
FSA	:	Faculty of Agronomic Sciences (in English)
HRH	:	Humboldt Research Hub
IF	:	Impact factor
INRAB	:	Institut National de la Recherche Agricole du Bénin (National Institute of Agricultural Research of Benin)
LABEF	:	Laboratoire de Biomathématiques et d'Estimations Forestières
MSc	:	Master of Sciences
Ph.D.	:	Doctor of Philosophy
RUFORUM	:	Regional Universities Forum for Capacity Building in Agriculture
UAC	:	University of Abomey-Calavi
UNA	:	Université Nationale d'Agriculture
UP	:	University of Parakou
WIF	:	Without Impact Factor

Statement of the head of the Lab

Dear colleagues and friends,

I am delighted, as usual, to introduce the 2023 annual report of the "Laboratoire de Biomathématiques et d'Estimations Forestières" (LABEF).

Thanks to the commitment of our members, partners, and collaborators, we have sustained our standards of scientific research and capacity building in Biostatistics, Forestry, Ecology, Conservation, and Agronomy. Our research and capacity building have in the last five years substantial extended to infectious diseases modelling as a strategic response to contemporary challenges in our region. I would like to take this opportunity to congratulate all the members for their consistent efforts and contributions to increasing the visibility of the laboratory through the quality of our research, training, and its relevance to society. Gratitude to our partners, collaborators, and donors, namely the Alexander von Humboldt foundation, the 2nd European & Developing Countries Clinical Trials Partnership (EDCTP2), the European Union (EU), the African Union (AU), the German Academic Exchange Service (DAAD), the International Union for Conservation of Nature (IUCN), JRS Foundation, the Lacuna Fund / Meridian Institute, the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM), the Académie de Recherche et d'Enseignement Supérieur (ARES), the International Foundation for Science (IFS), and the World Bank for their trust and support.

LABEF will continue to make climate change and biodiversity conservation, and mathematical and statistical modelling a priority of our research agenda to enlighten decision making to make life better in our region and continent.

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

Prof. Romain GLELE KAKAÏ

Head of 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.

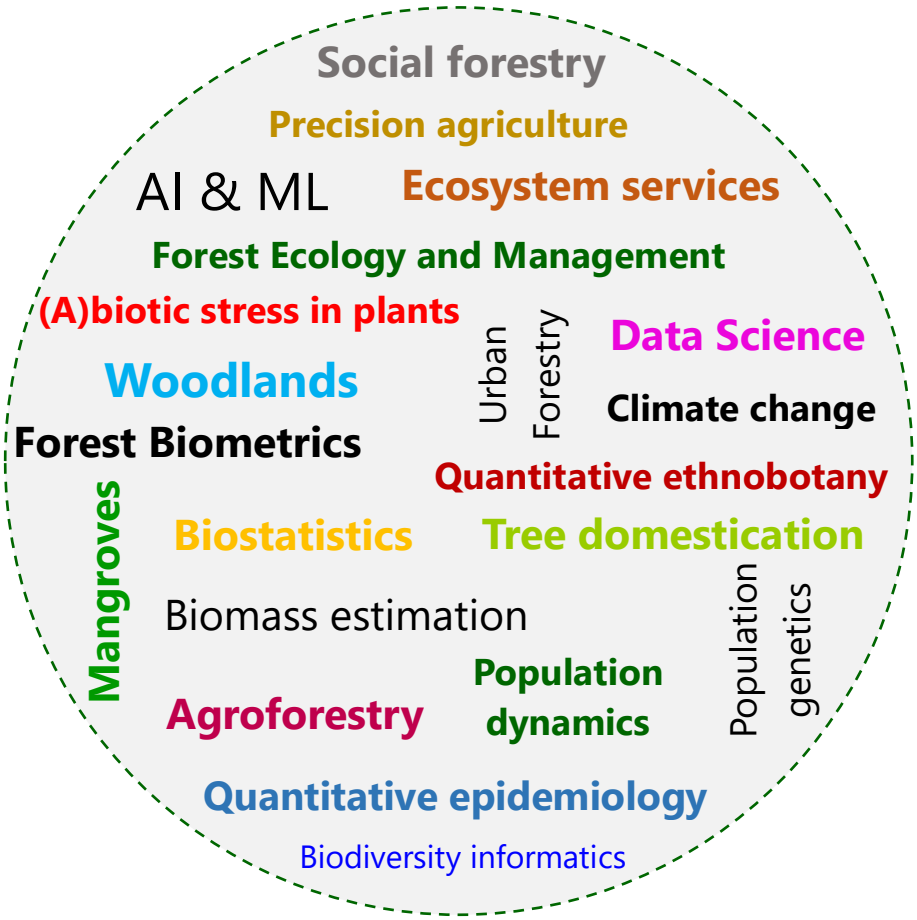

Figure 1. View of research topics covered at LABEF

1.4. The core management team of LABEF in 2023

Prof Romain GLELE KAKAÏ is the head of LABEF. He is a Full Professor in Biometry and Forestry, researcher, and lecturer at the Faculty of Agronomic Sciences. Prof GLELE KAKAÏ

is the chairman of the scientific council of agronomic sciences, chairman of the Scientific Council of the National Institute of Agricultural Research of Benin (INRAB), and chairman of the African German Network of Excellence in Science (AGNES). He is also coordinating the Doctoral program in Biometry at the University of Abomey-Calavi. His research areas include Linear and nonlinear mixed models - Generalized linear models - Multiblock data analysis - Forest estimations - Forest management.

Dr Jonas Doumate is the deputy head of LABEF and head of the Biomathematics research unit. He is Assistant Professor of Mathematics. His research areas include Applied mathematics – Analysis - Mathematical Statistics - Series Analysis – and Financial Mathematics.

Dr Emile Agbangba is the head of the Artificial Intelligence and Machine Learning research unit. His research areas include Machine Learning – Statistical Probability - Climate Science - Linear and nonlinear mixed models.

Dr Kolawolé Valère Salako is the scientific coordinator and head of the research unit in Forest estimations. He is a lecturer and researcher in Forestry and Biometry. His research areas include population and community ecology – Forest Biometrics – agroforestry systems analysis – multivariate methods in community ecology.

Dr Marcel Donou is the head of the social life department. He is also the Teaching manager of the Master Program: Major Biostatistics. His research areas include population Ethnobiology - Conservation Biology – Forest Biometrics.

Carl AKOTO is leading the administrative department. He oversees the administration and all related tasks. He assists the coordinator of the master program in statistics major Biostatistics for students' day-to-day management. He ensures that students have their timetable, receive their lectures, submit their homework, and sit their exams on time.

CHAPTER 2

RESEARCH: *Milestones & Highlights*

2.1. Scientific publications in 2023

2.1.1. Publications Milestones

In 2023, LABEF produced a total of 61 scientific documents. Among these documents (figure 2), 95.08% were scientific publications in peer-review journals (58 published papers), and 4.92% were books and book chapters (3 documents).

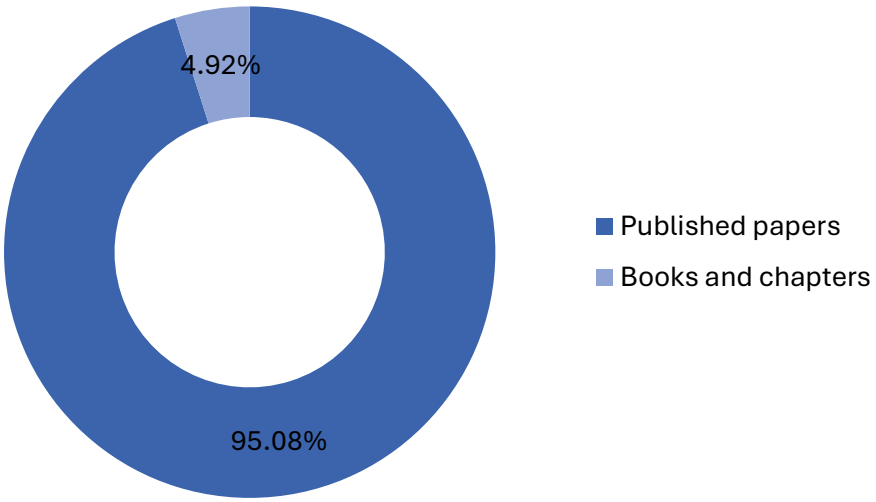

Figure 2. Scientific documents produced by LABEF in 2023

2.1.2. Diversity of Journals and scientific disciplines covered by publications of LABEF in 2023

In 2023, the 58 scientific articles were published in 44 journals as summarized in table 1. Several research domains were covered. Among the sixteen research domains covered, natural resources management (17 published papers), biostatistics (11 published papers), quantitative ethnobotany (6 published papers), climate change and biodiversity (5 published papers), biodiversity informatics (3 published papers), agroforestry (3 published papers), climate change and agriculture (2 published papers), ecology (2 published papers), ecology and Conservation (2 published papers), forestry (2 published papers), socio-economy (2 published papers), and soil sciences (2 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
Applied Vegetation Science	IF	2.8	1
Biomass and Bioenergy	IF	6	1
Biotechnology, Agronomy, Society and Environment	IF	1.087	1
Bois et Forêts des Tropiques	IF	0.6	1
Development in Practice	IF	1.2	1
Ecological Indicators	IF	6.9	1
Economic Botany	IF	2.6	1
Environment, Development and Sustainability	IF	4.9	1
Frontiers in Conservation Science	IF	1.7	2
Frontiers in Public Health	IF	5.2	2
Genetic Resources and Crop Evolution	IF	2	1
GeoJournal	IF	2.7	1
Global Ecology and Biogeography	IF	6.4	1
Global Ecology and Conservation	IF	4	4
Heliyon	IF	4	4
Journal of African Business	IF	1.9	1
Land	IF	3.9	1
Mathematical Biosciences and Engineering	IF	2.6	1
Modeling Earth Systems and Environment	IF	3.0	3
Natural Resources Forum	IF	3.3	1
PeerJ	IF	2.7	1
Science of the Total Environment	IF	9.8	1
Scientific Reports	IF	4.6	3
South African Journal of Botany	IF	3.1	2
South African Journal of Plant and Soil	IF	2.1	1
Sustainability	IF	3.9	1
Trees, Forests and People	IF	2.7	1
Vaccines	IF	7.8	1
African Journal of Applied Statistics	WIF	-	2
Afrika Statistika	WIF	-	1
Afrique SCIENCE	WIF	-	1
Applications Of Modelling And Simulation	WIF	-	1
Artificial Intelligence in Agriculture	WIF	-	1
Contemporary Mathematics	WIF	-	1
Environmental Systems Research	WIF	-	1
Journal of Applied Biosciences	WIF	-	1
Journal of Biological Research & Biotechnology	WIF	-	1
Plant-Environment Interactions	WIF	-	1
Research Application Summary	WIF	-	1
Revue Marocaine des Sciences Agronomiques et Vétérinaires	WIF	-	1
Annales de l'Université de Parakou Série Sciences Naturelles et Agronomie	WIF	-	1
Bulletin de la Recherche Agronomique du Bénin	WIF	-	1

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

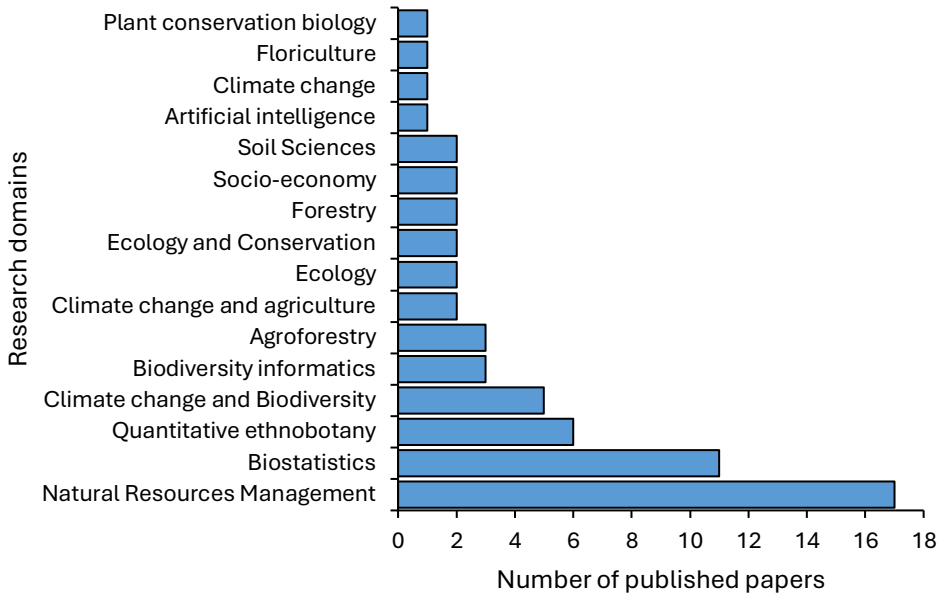

Figure 3. *Diversity of research domains for published papers by LABEF in 2023*

2.1.3. Performance and highlights in publication

LABEF produced slightly more scientific articles in 2023 than in 2022, and the trend has been increasing since 2014 (figure 4a). Among the 58 scientific publications in peer-review journals of 2023, 42 publications (72.41%) were in published in journals with an impact factor (figure 4b).

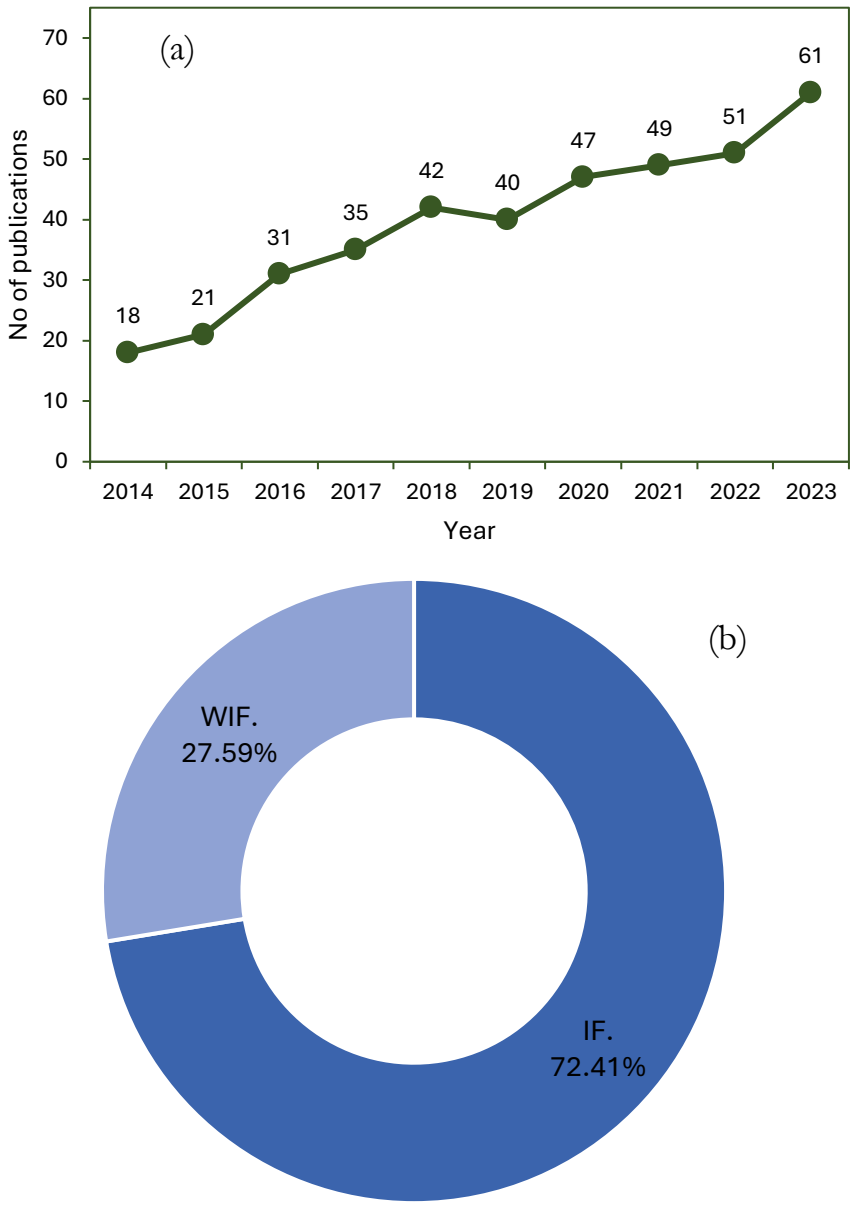

Figure 4. *Trends in annual publications from 2014 (a), and quality of publications (b). IF = Impact factored journals, WIF = Without impact factor journals*

Among the papers published in peer-review journals with an impact factor in 2023, 16.67% were in journals with an impact factor above 5, 64.29% in journals with an impact factor between 2 and 5, and 16.67% in journals with an impact factor between

1 and 2 (figure 6). This is a significant improvement of the standards in scientific publications.

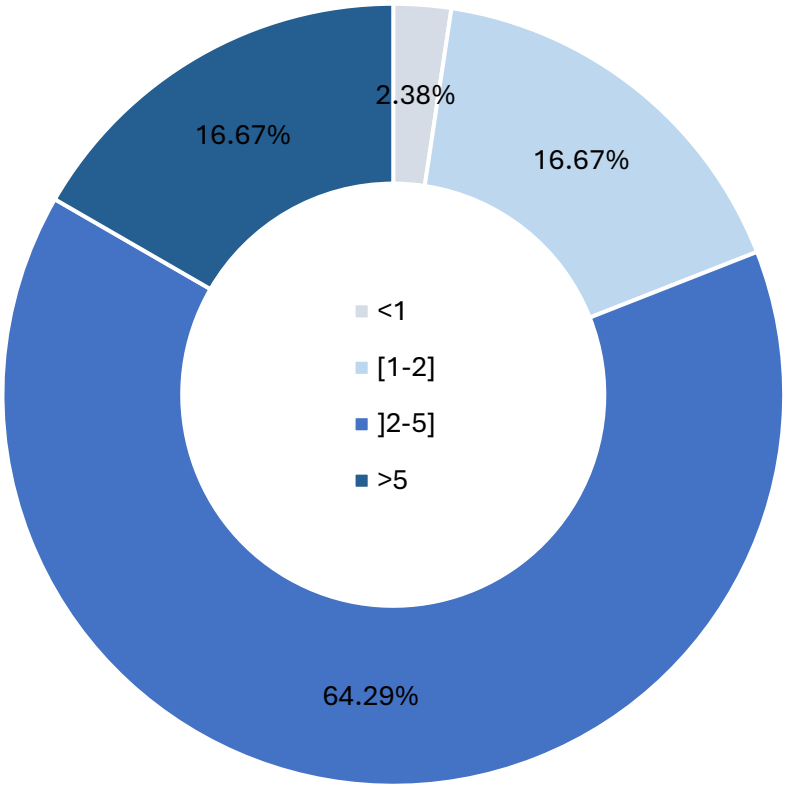

Figure 5. *Range of impact factor of published papers*

2.1.4. Authorship and leadership position in publications in 2022 and 2023

For the 61 scientific papers published in 2023, members of LABEF occupied variable positions. Members of the lab were exclusively the first author in eight published papers (13.79%). In nine of the published papers, members of LABEF were among the first three authors (figure 7). The leadership (last) position was occupied by members of the lab in 6.89% of the published papers, while in 27.58% of the papers, the last as well as the first positions were ruled by LABEF's members.

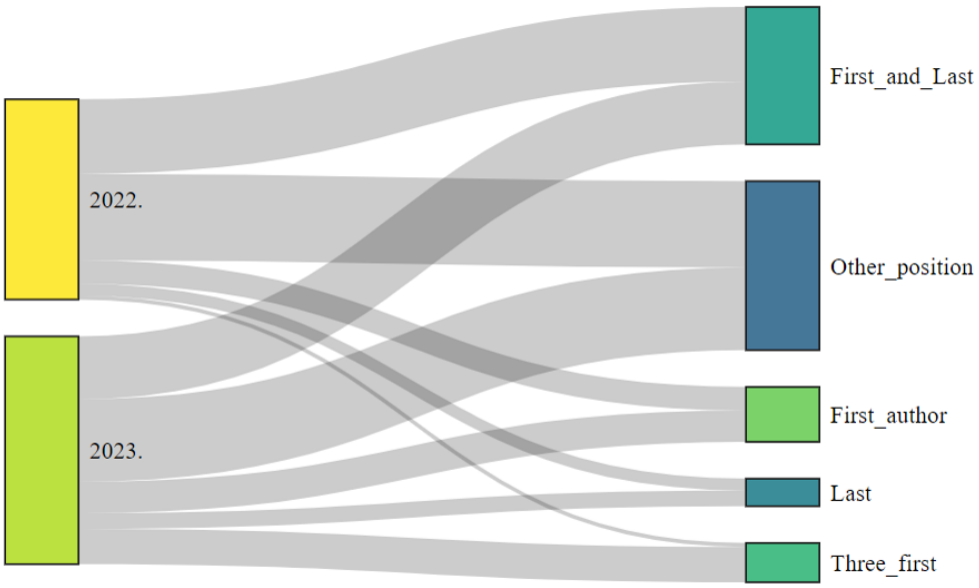

Figure 6. *(Co-) Authorship position of LABEF members in publications in 2023*

2.2. Research projects and fellowships in 2023

The research projects implemented by LABEF in 2023 included, as usual small (less than USD 25000), medium (USD 25 000-200 000), and large (more than USD 200 000) grants. Six individual small grants were implemented by members of LABEF in 2023 (see table 2).

Table 2. *Individual research grants and fellowships in LABEF in 2023*

N°	Funder	Recipient	Type	Topic/subject	Duration
1	TWAS-Elsevier Foundation	Sinasson Gisele K.	Research grant	Environmental restoration and creation of livelihoods through tree planting in the District of Manigri in Benin (West Africa	2 years
2	International Foundation for Science	Hounsou-Dindin Guillaume	Research grant	Towards the domestication of *Ricinodendron heudelotii* (Bail.) Pierre: insights from ecophenotypic assessment in Benin	3 years
3	Mawazo fellowship	Tahi Souand	Research grant	Optimization of machine learning methods and identification of the best model for predicting maize yield in Benin.	2 years
4	OWSD PhD fellowship	Orounla B. Rachidatou	Research grant	Interplay between personal characteristics, socio-economic determinants, environmental changes and disease outbreaks through causal modeling and structural equation modeling.	3 years
5	Make Our Planet Great Again (MOPGA) fellowship program for young researchers	Zanvo M.G. Serge	Post-doc fellowship	Capacity of climate changes mitigation by mangrove forests of Ramsar site 1018 (Benin) through assessment of their dynamics and carbon stock	2 years

Two medium and five large research projects are being implemented in LABEF in 2023 (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: www.labef-uac.org

Table 3. *Ongoing small, medium, and large collaborative research projects in LABEF in 2023*

N°	Project title	Project type	Partner countries	Funding institution	Period
1	Training epidemiologists and biostatisticians for enhanced response to disease outbreak and epidemic in west Africa – TEBWA	Large	Benin, United Kingdom	European and Developing Countries Clinical Trials Partnership (EDCTP2 / European Union)	2021-2023
2	Humboldt Research Hub Socio-Ecological Modeling of COVID-19 dynamics in Africa (HRH-SEMCA)	Large	Benin, Germany	Alexander von Humboldt Foundation	2021-2024
3	DELTAS Africa II. Sub-Saharan Africa Consortium for Advanced Biostatistics training. Role: coordinator in Benin (SSACAB)	Large	South Africa, Tanzanie, Malawi, DRC, Benin, Ghana, etc.	African Union	2021-2025
4	Accelerating inclusive green growth through Agri-based Digital Innovations in West Africa (AGriDI)	Large	West Africa	Agropolis fondation	2022-2025
5	Mobilizing and making data available for identification, taxonomy, socioeconomic importance, and conservation assessment of Bryophytes in Benin (BryoBen)	Medium	Benin	JRS Foundation	2023 - 2026
6	Recherche et action pour la restauration de *Conocarpus erectus* L., une espèce en voie de disparition dans les mangroves de la Bouche du Roy – île au sel et de la Commune de Ouidah, Bénin	Small	Benin	International Union for Conservation of Nature	2023 - 2024
7	Blue carbon and economy in West Africa: mobilizing datasets to better understand mangrove health in relationship to climate change	Medium	Benin	Lacuna Fund / Meridian Institute	2024 – 2025
8	Appui à la mise en place d'un master en One Health et analyse de risques sanitaires (Projet OHARIS)	Large	Benin, Belgium	ARES	2024 - 2028
9	WildSeed-Oil : Valorisation des graines de *Ricinodendron heudelotii* et *Momordica* spp., des sources d'acides gras bioactifs, pour promouvoir l'emploi et l'entrepreneuriat des femmes et des jeunes au Bénin (Afrique de l'Ouest)	Large	Benin, Belgium	ARES	2024 - 2028

N°	Project title	Project type	Partner countries	Funding institution	Period
10	Climate Smart mushrooms (*Pleurotus abalonus*) cultivation and processing as pathway for enhancing entrepreneurship, resilience, and food security of women in Benin (HOUNTO)	Medium	Benin	RUFORUM	2024 - 2026

2.3. Master, and Ph.D. degree dissertations in 2023

Nineteen (19) MSc students (5 females and 14 males) completed their MSc degree at LABEF (figure 7a). Among them, 16 were completed in biostatistics, 2 in biodiversity informatics and 1 in natural resources management (figure 7b).

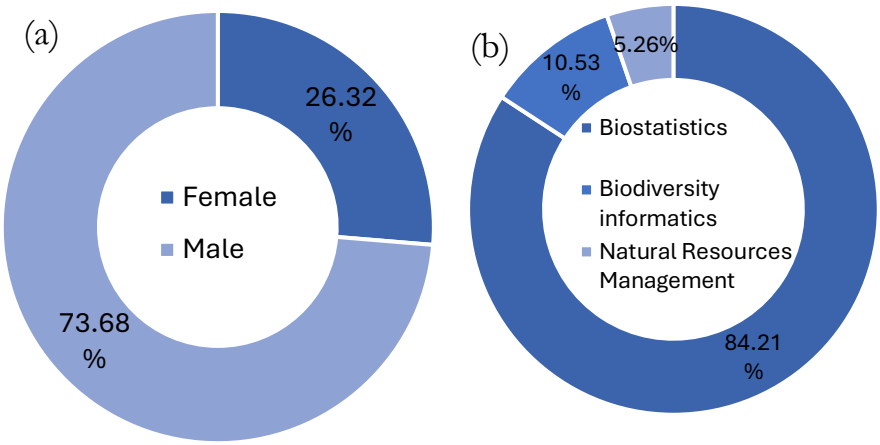

Figure 7. *Gender balance (a) and fields of research (b) for Master theses*

As far as Ph.D. students were concerned in 2023, one student defended his thesis in biometry. Twenty-seven Ph.D. initiatives are ongoing (9 females and 21 males). These Ph.D. initiatives covered several research domains, with, biometry being the most investigated discipline (24 initiatives, see figure 8a). Moreover, 40% of the Ph.D. students are in their second year, while 3.33% are respectively in their sixth and seventh years in 2023 (figure 8b).

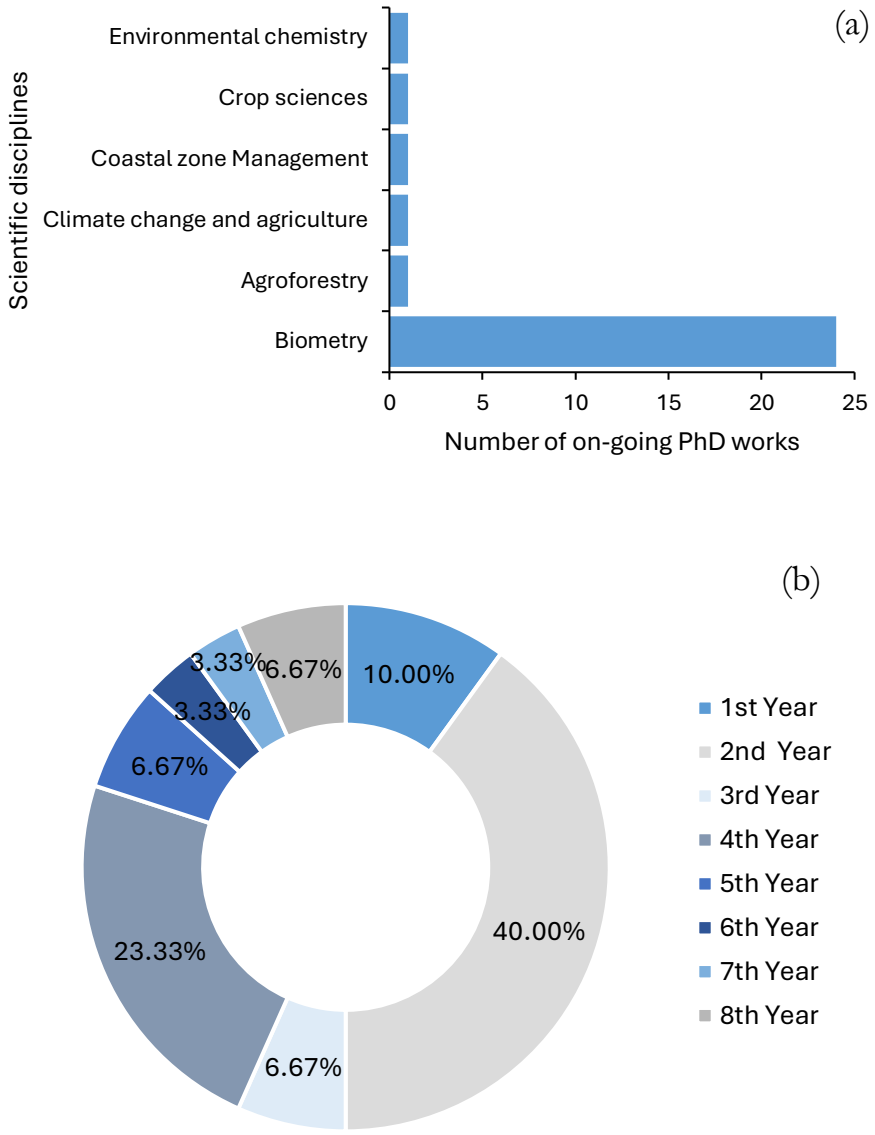

Figure 8. *Fields of research (a) and stages of ongoing Ph.D. theses in 2023*

CHAPTER 3

RESEARCH: *Connection, share, and networking*

3.1. Collaboration for publication in 2023

Collaboration for publications was done with researchers from several countries. In 2023, LABEF members collaborated with researchers from 24 countries, national collaborations being the most dominant (61.90%, figure 10a). The most represented continent for these collaborations was Africa more than 88.10%, followed by Europe more than 7.74% (figure 10b).

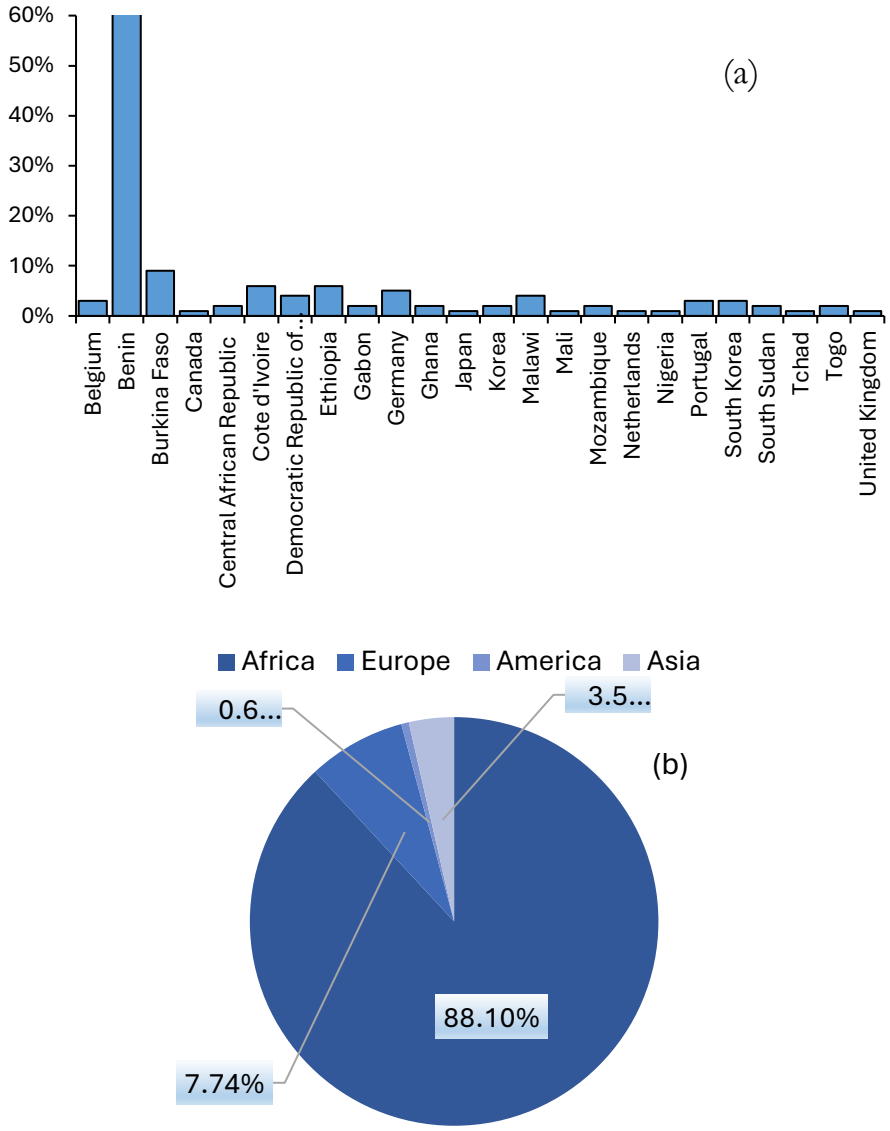

Figure 9. Countries (a) and world regions (b) of co-authors of publications of LABEF in 2023

3.2. Visiting researchers and post-docs to LABEF in 2023

In 2023, LABEF received five international post-Doctoral researchers from three countries (Burkina-Faso, Côte d'Ivoire, and USA) for visiting research.

N°	Name	Sex	Level	Research topic	Funder	Country	Supervisor(s)	Period
1	Tiétiambou Fanta	F	Post-Doc	Combining local perception and ecological niche modelling to understand vulnerability to climate change of priority crops and native woody food species used during the period of food shortage in Burkina Faso	DAAD ClimapAfrica	Burkina-Faso	Prof. Romain Glèlè Kakaï & Dr Achille Hounkpèvi	March 2022 – February 2023
2	Lynch Lauren	F	Post-Doc	Impacts of Urbanization on Bees and Pollination Services in Abomey-Calavi	Fullbribgt Fellowship	USA	Prof. Romain Glèlè Kakaï & Dr Gbedomon Castro & Dr Valère Salako	Sept 22 – June 23
3	Sabo Prosper	M	Post-Doc	Influence of seed and substrates in enhancing the sexual propagation of *Boswellia dalzelii* Hutch.	TWAS Fellowships for Research and Advanced	Burkina-Faso	Prof. Romain Glèlè Kakaï & Dr Valère Salako	November 2023 – May 2024
4	Assale Yvette	F	Post-Doc	Connaissances endogènes des services d'approvisionnement fournis par les plantes ligneuses des systèmes agroforestiers à base de cacaoyers au Centre-Ouest de la Côte d'Ivoire	Centre d'Excellence Africain sur le Changement Climatique, la Biodiversité et l'Agriculture	Côte d'Ivoire	Prof. Romain Glèlè Kakaï Dr Valère Salako Dr Achille Hounkpevi	Janvier – Février 2023
5	Koua Noel	M		Modélisation du paysage agricole à l'ouest de la côte d'ivoire face au changement climatique				

					Durable (CEA-CCBAD)			
6	Five graduate students from USA	4F and 1M	Master	Summer Tropical Ecological Research in Benin (https://volweb.utk.edu/~ogaoue/NSFinBenin.html)	NSF	USA	Prof. Romain Glèlè and Prof Orou G. Gaoué	May – June 2023

Figure 10. Statistical sampling workshop led by Prof. Romain Glèlè Kakai for the 2nd cohort of the Summer Tropical Ecological Research in Benin in partnership with the University of Tennessee in USA.

CHAPTER 4

CONTRIBUTION: *Capacity building*

4.1. Graduate program in Biostatistics and Doctoral program in Biometry

4.1.1. Graduate program in Biostatistics (MBIOST)

4.1.1.1. 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 Bachelor's Degree holders in Life Sciences domains (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 in Biostatistics has fully trained and released seven batches of professional biostatisticians and data analysts. The 11th batch of students started in September 2023 and enrolled 26 students from 05 countries (Benin, Burundi, Kenya, Mali and Nigeria). To date, 237 students were trained or are completing their degree in the program. The program is supported by an Intra-ACP Academic Mobility Program (AGREEMENT NUMBER 2013-4177/001-001), RUFORUM, the German Federal Ministry of Education and Research through DAAD In-Country/In Region Program, and the African Excellence Center for Mathematics Sciences and Application (ACE-MSA, through World Bank Group fund).

4.1.1.2. 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 Organization (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 valorization 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.

4.1.1.3. How to apply?

Visit the website www.labef-uac.org and fill in the online application form (http://labef-uac.org/application). 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 (http://labef-uac.org/en/master/).

4.1.2. Doctoral program in Biometry

In addition, since 2017-2018, the doctoral school of agronomic sciences and water resources has been offering a Ph.D. program in Biometry under the coordination of Prof Romain GLELE KAKAÏ (the head of LABEF and coordinator of the master's program in Biostatistics). Seven new members of LABEF who graduated from the Master's program in Biostatistics are currently enrolled in the PhD program. Thus, to date, 29 students are enrolled in the Ph.D. program, and some are close to their thesis defence and 09 graduated.

CHAPTER 5

SERVICES TO SOCIETY

5.1. Development of updated and specific allometric models and understanding the impacts of silvicultural interventions on exploitable wood and the quality/quantity of charcoal of *Acacia auriculiformis* for the "Projet Forêt Classées du Bénin" (PFC – Bénin)

The Benin Classified Forests Project (PFC-Benin), developed with the support of the World Bank, started on October 1st, 2019, for a period of seven (7) years. The development objective of the project is to improve the integrated management of targeted classified forests, facilitate access of the main consumption centres to sustainably produced wood energy, promote the value chain of targeted Non-Timber Forest Products (NTFP) to improve the income of forest-dependent communities. PFC-Benin addresses the main factors of deforestation and degradation in targeted gazetted Forests (GF) and aims to establish 22,000 ha of plantations including 15,000 ha of energy wood and 7,000 ha of timber. These forest plantations are being established eight (08) gazetted Forests, namely Dan, Logozohè, Ouémé-Boukou, Kétou, Agoua, and Tchaourou Toui Kilibo for energy wood plantations and, Dogo and Lama-Sud for energy wood plantations.

The Project is coordinated by an Integrated Project Management Unit in the Environment and Natural Resources sector funded by the World Bank; and the national management of the project is provided by the General Directorate of Water, Forests and Hunting (DGEFC).

On the ground, the activities of PFC-Benin are implemented by:

a) The Technical Forest Management Units (CTAF) which are specialized decentralized units of the Forestry Administration dedicated to the management of classified forests. The CTAFs operate under the supervision of the DGEFC through the territorially competent Forest Inspections (FI).
b) The National Wood Company (SONAB) which operates in two forests (Dogo and Lama south).

After 4 years of implementation of PFC-Benin, 18,748 ha of energy wood plantations and 5,807 ha of timber plantations have been established. In the field, differences were observed in terms of growth among plantations of the same age in the same forest and from one gazetted forest to another. This suggests that wood productivity differs between climatic zones on the one hand, and between soil types within the same forest on the other hand. The data currently available indicate a rotation of 7 years for a possible cutting of 120m^3/ha of wood and concern a climatic zone (southern Benin) different from the zone where the PFC-Benin plantations are installed. The concern today is to mobilize additional data to (i) develop updated and specific allometric equations for wood volume estimation for the different climatic zones, soil types, and silvicultural interventions to accurately predict the volume of wood and rotation in

each forest; and (ii) understand the impact of silvicultural treatments on the volume of exploitable wood and the quality/quantity of charcoal.

To this end, PFC-Benin requested the assistance of the Laboratory of Biomathematics and Forest Estimates (LABEF) to conduct, together with the Applied Forestry Research Unit of the DGEFC, specific research work on *A. auriculiformis* in the intervention sites of PFC-Benin. A methodological guideline was developed by LABEF to:

- Evaluate the effect of climatic zone, soil type, and silvicultural treatments on the productivity and optimum growth of *A. auriculiformis* in the PFC – Benin plantations;
- Establish allometric equations for wood volume estimation for *A. auriculiformis* based on the climatic regions and soil types of the PFC – Benin plantation sites;
- Evaluate the effect of climatic zone, soil type, and silvicultural treatments on wood quality and charcoal yield.

The data collection will soon start.

APPENDIX 1.

Scientific activities in 2023

A1.1. PhD theses defense in 2023

Name	Sex	Research topic	Research field
EHNON Gongnet Emmanuel	M	Empirical assessment of Bayesian Maximum Entropy (BME) robustness in spatial estimation application on soil data	Biometry

A1.2. On-going theses in 2023

N°	Name	Sex	Level	Topic	Field of research
1	Sonon Bienvenu	M	1st year	Application of artificial intelligence in combination with exponential autoregressive to model rainfall onset-cessation for the improvement of agriculture planning in Benin	Biometry
2	Tinhoun fréjus Stéphane Sèdjro Cossi	M	1st year	Understanding the impacts of interventions on COVID-19 dynamics in West Africa: a hybrid Bayesian machine learning framework	Biometry
3	SODE Akoeugnigan Idelphonse	M	1st year	Spatial Fusion Framework for the Joint Analysis of Geospatial Data from Multiple Sources: Ecological and Epidemiological Applications	Biometry
4	Constant Setondé Gnansounou	M	2st year	Social-Ecological Resilience of Mangroves in Benin	Coastal zone Management
5	ZINZINHEDO Mahoukpégo Luc	M	2st year	Combined approach of Machine Learning and spatiotemporal models for cassava (*Manihot esculenta* C.) yield prediction in Benin under pathogen infestation conditions.	Biometry
6	GUEDEZOUME Behanzin Marthe Paulette	F	2st year	Using machine learning techniques to predict soil fertility in Benin	Biometry
7	TRAORE Kassifou	M	2st 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.	Biometry
8	ODOUNFA Mireille Gloria F.	F	2st year	Using deep learning techniques for early detection of chili (*Capsicum* spp, Tailor and Francis) diseases under constraints of limited sample image, climate variations, and pests.	Biometry
9	Dereje Gebeyehu Ababu	M	2st year	Cointegration of Markets and Their Impact on Income and Productivity of Cereal Crops Producing Households: The Case of Ethiopia	Biometry
10	BEH MBA Romuald	M	2st year	Empirical performance of Generalized linear mixed model for point-referenced spatial data with Application to epidemiological data: Disease Mapping	Biometry
11	DETE Houénafa Clarisse	F	2st year	Relative performance of model selection criteria based on Kullback's symmetric Divergence in survival analysis with application in animal production	Biometry
12	ANTENEH Leul Mekonnen	M	2st year	Modeling of Cholera Epidemics in Ethiopia	Biometry
13	MONTCHO Yvette	F	2st year	Socio-Ecological and spatio-temporal Modeling of COVID-19 dynamics in Africa	Biometry
14	ADEOTI Olaiya Mathilde	M	2st year	Bayesian nonlinear modelling for correlated epidemic data using flexible distribution: A Casablanca study with COVID-19 data	Biometry

N°	Name	Sex	Level	Topic	Field of research
15	AKIN Y. Yanik	M	2st year	Phylogenetic diversity, perturbation, and transient dynamic of tropical fuelwood tree	Biometry
16	AGBANGBA Codjo Emile	M	3nd year	Experimental designs and data analysis with linear model in the presence of spatial autocorrelation with applications in soil sciences	Biometry
17	OROUNLA Bissilimou Rachidatou	F	3nd year	Interplay between personal characteristics, Socio-economic determinants, environmental changes and diseases through Causal Modeling and Structural Equation Modeling	Biometry
18	TABOE Hemaho Beaugard	M	4rd 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.	Biometry
19	TAHI Souand Peace Gloria	F	4rd year	Artificial Intelligence-based problem-solving in agricultural yield prediction: Optimization of Ensemble Learning techniques performances and ability of base regressors in the prediction of yield of maize cultures under several controlled weather and fertilization patterns	Biometry
20	MUSHAGALUSA Ciza Arsène	M	4rd year	Practical use of Random Forest regression for count response data and diseases' vectors abundance prediction: application to ticks (*Rhipicephalus appendiculatus*) abundance in grazed permanent pastures	Biometry
21	HOUETOHOSSOU Ariane	F	4rd year	Architectural and parametric optimization of pre-trained Convolutional Neural Network (CNN) application on stress detection on tomato plants under climate and infection based simulated environments	Biometry
22	BOUROBOU Judie Armel	M	4rd year	Inhomogeneous Poisson Process and its extensions for species distribution analysis: Accounting for sampling bias, imperfect detection, non-linear effect and spatial dependence.	Biometry
24	MUGUMAARHAHAMA Yannick	M	4rd year	Spatial point process model for analysis of presence-only data: accounting for species characteristics and uncertainties in data	Biometry
23	DAH-DOVONON Virgile-Marx	M	4rd 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
25	KAKPO Dolou Angeline Reine	F	5th year	Uses, fertilizing power, populations dynamic and conservation of some agroforestry species high soil fertilizing potential in Benin.	Agroforestry
26	DONHOUEDE Janine	F	5th year	Morphological variation, genetic diversity and proximate composition in *Annona senegalensis* in Western and Southern Africa	Natural Resources Management
27	AHLONSOU Biowa Ceptime Galilée	M	6th year	Empirical performance of Distance functions for farm efficiency analysis application on organic cotton farming systems in Benin	Biometry
28	AMAGNIDE Aubin	M	7th year	Empirical studies of plotless sampling techniques in vegetation studies	Biometry
29	WABI Moudjahid Akorédé	M	8th year	Variabilités climatiques et riziculture au Bénin : cas des communes de Malanville, Glazoué et Tanguiéta	Crop sciences
30	ECLOU Innocent Sènandé Benjamin	M	8th year	Assessing the potential of organic cotton production to improve the livelihoods of millions of poor households in Sub-Saharan Africa (SSA)	Environmental chemistry

A1.3. Completed Master in 2023

N°	Name	Sex	Topic	Supervisor(s)	Field of research
1	AGBI Delight M.	F	Eco-epidemiology of Lassa fever virus: a modeling approach	Prof Romain GLELE KAKAÏ Dr. Jonas T. DOUMATE	Biostatistics
2	SESAY Marwan V.	M	Machine Learning-based modeling of Malaria: A review.	Prof. Romain GLELE KAKAÏ Dr. Ratheil HOUNDJI	Biostatistics
3	TUO O. Nicolas	M	A Partial Least Square structural equation model in assessing the risk perception and the impacts of non-conventional medicine on COVID-19 in West Africa	Prof. Romain GLELE KAKAÏ Dr. Codjo Émile AGBANGBA	Biostatistics
4	HOUNKONNOU Mitonsou Tierry	M	Improving Kriging methods performance using Box-Cox transformation on highly skewed data	Prof. Romain GLELE KAKAÏ Dr. Codjo Émile AGBANGBA	Biostatistics
5	AGON Vidjinnassou Jacques	M	Kriging And Bayesian Maximum Entropy Robustness to Kurtosis and Skewness: Simulation-Based Analysis	Prof. Romain GLELE KAKAÏ Dr. Codjo Émile AGBANGBA	Biostatistics
6	GNONLONFOUN Isidore	M	Bayesian analysis of COVID-19 spread dynamic in Africa	Prof. Romain GLELE KAKAÏ Dr Charlemagne GBEMAVO	Biostatistics
7	AYIHOU Sèna Yannick	M	Mathematical modelling and transmission dynamics analysis of African Swine Fever Virus in Benin	Prof. Samuel BOWONG TSAKOU Prof. Romain GLELE KAKAÏ	Biostatistics
8	ESSETCHEOU Scholastique M. Merveille	F	Count time series with covariates models and application to Lassa fever data	Prof. Romain GLELE KAKAÏ Dr. (MC) Freedath DJIBRIL MOUSSA	Biostatistics
9	DAKO Sidoine Aude Sèdami	M	Assessing the effect of non-pharmaceutical interventions on the transmission of SARS-CoV-2 across Africa: a compartmental modeling study	Prof Romain GLELE KAKAÏ Dr. Jonas T. DOUMATE	Biostatistics
10	NIYOMWUNGERE Nicole	F	Performance of Generalized Linear Mixed Models for Assessing Association Between a Binary Outcome and an Intervention: Application to the School Canteen Program in Burundi (2018 to 2022)	Prof. Romain GLELE KAKAÏ Dr Charlemagne GBEMAVO	Biostatistics
11	HATEGEKIMANA Nathanael	M	Modeling and mapping the risks of zoonoses outbreaks in Burundi	Prof. Romain GLELE KAKAÏ Dr David NIYUKURI Dr. Charlemagne GBEMAVO	Biostatistics
12	NWOGIJI Olando Cletus	M	Improving Forecasting in milk-yield Production in Diary Cattle: A Comparative Evaluation of Random Regression Model with Legendre Polynomials and Artificial Neural Network.	Prof Marcel SENOU	Biostatistics
13	TCHEDE Amèdjiko Bruno	M	Performance of linear mixed effect models in analysis of variance of common experimental design accounting for spatial autocorrelation	Prof. Romain GLELE KAKAÏ Dr. Codjo Émile AGBANGBA	Biostatistics
14	YALINKPON Florent	M	On the relative performance of DRIS, M-DRIS and CND models in crop nutrient diagnosis	Prof. Romain GLELE KAKAÏ Dr. Codjo Émile AGBANGBA	Biostatistics
15	TCHANDO Sika Fidèle	M	On post-hoc tests robustness to group size, non-normality and heteroscedasticity in Linear Mixed Effects Model: A simulation study	Prof. Romain GLELE KAKAÏ Dr. Codjo Émile AGBANGBA	Biostatistics

16	LADEKAN B. M. A. Floriane	F	Predicting Chronic Kidney Disease Stages using Machine Learning Techniques	Prof. Romain GLELE KAKAÏ Prof. Jacques VIGAN Dr. Ratheil HOUNDJI	Biostatistics
17	TOKANNOU Ludovic	M	Niches écologiques de *Zea mays* L., *Sorghum bicolor* (L.) Moench, de leur ravageur *Spodoptera frugiperda* (JE Smith) (*Lepidoptera : Noctuidae*) et de son parasitoïde larvaire *Coccygidium luteum* (Braconidae : Hymenoptera) (Brulle, 1846) : enseignements pour la protection des cultures dans le contexte des changements climatiques	Prof Romain GLELE KAKAÏ	Biodiversity informatics
18	GOUDOU Merveille Trinité	F	Distribution spatiale du Touraco vert (*Tauraco persa*) et de ses ressources alimentaires (*Dialium guineense* et *Musanga cecropioides*) : enseignements pour leur conservation dans le contexte des changements climatiques	Prof Romain GLELE KAKAÏ	Biodiversity informatics
19	AGONTINGLO Eminor Loïck T.	M	Diversité et formes d'utilisation des espèces du genre Momordica (Cucurbitaceae) en zone soudano-guinéenne du Bénin	Prof Romain GLELE KAKAÏ	Natural Resources Management

A1.4. Scientific papers published in peer-review journals IF in 2023

N°	Discipline	Authors' Names	Title of the article	Journals	IF
1	Climate change and Biodiversity	Lokonon B.E., Gbemavo C. D.S.J., Agounde G., Simbo D., Samson R., Glèlè Kakaï R.	Modelling the current and future distribution of *Caesalpinia bonduc* (L.) Roxb: Its implication for future conservation of the species in the Southern Benin	African Journal of Ecology	1
2	Climate change and Biodiversity	Daï H.E., Houndonougbo J.S.H., Idohou R., Ouédraogo A., Glèlè Kakaï R., Hôtes S., Assogbadjo A.E.	Modeling current and future distribution patterns of *Uvaria chamae* in Benin (West Africa): Challenges and opportunities for its sustainable management	Heliyon	4
3	Biostatistics	Montcho Y., Klingler P., Lokonon B.E., Tovissodé C.F., Glèlè Kakaï R., Wolkewitz M.	Intensity and lag-time of non-pharmaceutical interventions on COVID-19 dynamics in German hospitals	Frontiers in Public Health	5.2
4	Climate change and Biodiversity	Kochoni B.I., Avakoudjo H.G.G., Kamelan T.M., Sinsin C.B.L., Kouamelan E.P.	Contribution of mangroves ecosystems to coastal communities' resilience towards climate change: a case study in southern Cote d'Ivoire	GeoJournal	2.7
5	Natural Resources Management	Sabo P., Ouédraogo A., Lankoandé B., Salako K.V., Ouédraogo H., Glèlè Kakaï R.	Influence of topography on the natural stand structure of *Boswellia dalzielii* Hutch. in a semi-arid environment: Insight into hill ecosystems conservation in Burkina Faso	Global Ecology and Conservation	4
6	Natural Resources Management	Zerbo I., Salako K.V., Hounkpèvi A., Zozoda D., Glèlè Kakaï R., Thiombiano A.	Impact of climate patterns, land-use types and exploitation on the population structure of Bombax costatum Pellegr. and Vuillet in West African semi-arid savannas	Global Ecology and Conservation	4
7	Quantitative ethnobotany	Vihotogbé R., Avocèvou-Ayisso C., Djikpo R., Teka O., Sinsin B., Glèlè Kakaï R.	Folk taxonomical distinction between *Irvingia gabonensis* and *I. wombolu* (Irvingiaceae) in the Volta Forest region, West Africa	Biotechnology, Agronomy, Society and Environment	1,087
8	Ecology and Conservation	Mensah S., Lokossou C.J.M., Assogbadjo A.E., Glèlè Kakaï R.	Seasonal variation of environment and conspecific density-dependence effects on early seedling growth of a tropical tree in semi-arid savannahs	Global Ecology and Conservation	4
9	Natural Resources Management	Akpovo A.H., Honfo S.H., Fandohan A.B.	Geographical distribution, abundance and population structure of *Ricinodendron heudelotii* (Baill.) Pierre ex. Heckel, a culturally important species in Benin Republic	South African Journal of Botany	3.1
10	Biostatistics	Montcho Y., Nalwanga R., Azokpota P., Doumatè J.T., Lokonon B.E., Salako V.K., Wolkewitz M., Glèlè Kakaï R.	Assessing the Impact of Vaccination on the Dynamics of COVID-19 in Africa: A Mathematical Modeling Study	Vaccines	7.8
11	Natural Resources Management	Dassou G.H., Favi G.A., Salako K.V., Ouachinou J.M.A.S, Trekpo P., Akouete P., Agounde G., Djidohokpin D., Dansi M., Kouyaté A.M., Natta A.K., Yedomonhan H., Adomou A.C.	An updated review of the African multipurpose tree species *Detarium senegalense* J.F.Gmel. (Fabaceae)	South African Journal of Botany	3.1
12	Biostatistics	Lokonon B.E., Montcho Y., Klingler P., Tovissodé C.F., Glèlè Kakaï R., Wolkewitz M.	Lag-time effects of vaccination on SARS-CoV-2 dynamics in German hospitals and intensive-care units	Frontiers in Public Health	5.2

N°	Discipline	Authors' Names	Title of the article	Journals	IF
13	Biodiversity informatics	Hounsou-Dindin G., Idohou R., Donou Hounsode M.T., Adomou A.C., Assogbadjo A.E., Glèlè Kakaï R.	Climate change effects on desert date *Balanites aegyptiaca* (L.) Delile in Benin: Implications for conservation and domestication	Natural Resources Forum	3.3
14	Natural Resources Management	Sinsin C.B.L., Bonou A., Salako K.V., Gbedomon R.C., Glèlè Kakaï R.	Economic Valuation of Mangroves and a Linear Mixed Model-Assisted Framework for Identifying Its Main Drivers: A Case Study in Benin	Land	3.9
15	Socio-economy	Thoto F.S., Djana B., Mignouna D.B., Adeoti R., Gbedomon R.C., Chogou S.K., Aoudji A., Honfoga B.	Explaining the Positioning of Agricultural Entrepreneurs on the Necessity-Opportunity Continuum in Sub-Saharan Africa: Insights from Benin	Journal of African Business	1.9
16	Climate change and Biodiversity	Mensah S., Noulèkoun F., Salako K.V., Lokossou C.S.M.J., Akouété P., Seifert T., Glèlè Kakaï R.	Structural and taxonomic diversity predict above-ground biomass better than functional measures of maximum height in mixed-species forests	Applied Vegetation Science	2.8
17	Climate change and Biodiversity	Biaou S., Gouwakinnou G.N., Noulèkoun F., Salako K.V., Houndjo Kpoviwanou J.M.R., Houehanou T.D., Biaou H.S.S.	Incorporating intraspecific variation into species distribution models improves climate change analyses of a widespread West African tree species (*Pterocarpus erinaceus* Poir, Fabaceae)	Global Ecology and Conservation	4
18	Biostatistics	Matazi A.K., Gognet E.E., Glèlè Kakaï R.	Digital soil mapping: a predictive performance assessment of spatial linear regression, Bayesian, and ML-based models	Modeling Earth Systems and Environment	3.0
19	Biostatistics	Yedomonhan E., Tovissodé C.F., GLELE Kaka R.	Modeling the effects of Prophylactic behaviors on the spread of SARS-CoV-2 in West Africa	Mathematical Biosciences and Engineering	2.6
20	Ecology and Conservation	Mensah S., Noulèkoun F., Dimobe K., Seifert T.,Glèlè Kakaï R.	Climate and soil efects on tree species diversity and aboveground carbon patterns in semi-arid tree savannas	Scientific Reports	4.6
21	Forestry	Zanvo S.M.G., Mensah S., Salako K.V., Glèlè Kakaï R.	Tree height-diameter, aboveground and belowground biomass allometries for two West African mangrove species	Biomass and Bioenergy	6
22	Natural Resources Management	Donhouedé J.C.F., Marques I., Salako K.V., Assogbadjo A.E., Ribeiro N., Ribeiro-Barros A.I.F.	Genetic and morphological diversity in populations of *Annona senegalensis Pers.* occurring in Western (Benin) and Southern (Mozambique) Africa	PeerJ	2.7
23	Natural Resources Management	Donhouedé J.C.F., Salako K.V., Assogbadjo A.E., Ribeiro-Barros A.I.F., Ribeiro N.	The relative role of soil, climate, and genotype in the variation of nutritional value of *Annona senegalensis* fruits and leaves	Heliyon	4
24	Natural Resources Management	Manda L., Salako K.V., Kataya A., Affossogbe T., Njera D., Mgoola W.O., Assogbadjo A.E., Sinsin B.	Co-management brings hope for effective biodiversity conservation and socio-economic development in Vwaza Marsh Wildlife Reserve in Malawi	Frontiers in Conservation Science	1.7

N°	Discipline	Authors' Names	Title of the article	Journals	IF
25	Climate change and agriculture	Wabi M.A., Vanhove W., Idohou R., Hounkpèvi A., Glèlè Kakaï R., Van Damme P.	Midterm change in Rainfall distribution in north and central Benin: implications for agricultural decision making	Environment, Development and Sustainability	4.9
26	Quantitative ethnobotany	Deguenonvo T.A.G, Houéhanou T.D., Idohou R., Yehouenou N., Gouwakinnou G.N., Natta A.K.	Uses, Cultural Importance, and Fire Threat to *Pseudocedrela kotschyi* (Meliaceae): Evidence for the Availability Hypothesis in Benin (West Africa)	Economic Botany	2.6
27	Agroforestry	Kakpo A.R., Vodounnon M.J., Agbangba E.C., Hounsou-Dindin G., Dagbénonbakin D.G., Amadji G.L., Buri M.M., Glèlè Kakaï R.	Vulnerability of *Parkia biglobosa, Vitellaria paradoxa* and *Vitex doniana* to climate change: wild indigenous agroforestry species in Benin	Modeling Earth Systems and Environment	3.0
28	Biodiversity informatics	Hounsou-Dindin G., Idohou R., Agre P., Hounkpèvi A., Adomou A.C., Assogbadjo A.E.,Glèlè Kakaï R.	Habitat range shift and prediction of the potential future distribution of *Ricinodendron heudelotii (Baill.) Heckel* in Benin (West Africa)	Heliyon	4
29	Quantitative ethnobotany	Biaou B., Gouwakinnou G.N., Noulèkoun F.,Salako K.V., Noumagnan N.B.A., Ahouandjinou E.B.O., Houéhanou T.D.	Insights from analyzing local ecological knowledge and stand structure for guiding conservation actions for the endangered tropical tree *Pterocarpus erinaceus. Poir*	Trees, Forests and People	2.7
30	Forestry	Zanvo S.M.G., Salako K.V. Mensah S., Glèlè Kakaï R.	Impacts of harvesting intensity on carbon allocation to species, size classes and pools in mangrove forests, and the relationships with stand structural attributes	Ecological Indicators	6.9
31	Natural Resources Management	Mensah S., Dimobe K., Noulèkoun F., van der Plas F., Seifert T.	Phylogenetic diversity and community wide-trait means offer different insights into mechanisms regulating aboveground carbon storage	Science of the Total Environment	9.8
32	Natural Resources Management	Lokonon B.E., Mangamana E.T., Glèlè Kakaï R.	Residents' perception and impact of COVID-19 on ecotourism in West Africa: The case of Banco National Park inCôte d'Ivoire	Heliyon	4
33	Climate change	Deguenon S.D.D.M., Hounmenou C.G., Adade R., Teka O., Toko I.I., Aheto D.W., Sinsin B.	Simulation of the Impacts of Sea-Level Rise on Coastal Ecosystems in Benin Using a Combined Approach of Machine Learning and the Sea Level Affecting Marshes Model	Sustainability	3.9
34	Quantitative ethnobotany	Ganka G., Fandohan A.B., Salako K.V.	Impacts of taboos and ritual ceremonies on the population structure of a sacred tree in Benin, *Triplochiton scleroxylon K. Schum*	Bois et Forêts des Tropiques	0.6
36	Natural Resources Management	Noulèkoun F., Mensah S., Kim H., Jo H., Gouwakinnou G.N., Houéhanou T.D., Mensah M., Naab J., Son Y., Khamzina A.	Tree size diversity is the major driver of aboveground carbon storage in dryland agroforestry parklands	Scientific Reports	4.6
37	Natural Resources Management	Noulèkoun F., Mensah S., Dimobe K., Birhane E., Kifle E.T., Naab J., Son Y., Khamzina A.	Both the selection and complementarity effects underpin the effect of structural diversity on aboveground biomass in tropical forests	Global Ecology and Biogeography	6.4

N°	Discipline	Authors' Names	Title of the article	Journals	IF
38	Biodiversity informatics	Alier G., Idohou R., Hounsou-Dindin G., Glèlè Kakaï R.	Assessing the potential impact of climate change on Kobus megaceros in South Sudan: a combination of geostatistical and species distribution modelling	Modeling Earth Systems and Environment	3.0
39	Socio-economy	Kaki R.S., Houessou D.M., Gbedomon R.C., Thoto F.S., Gandji K., Aoudji A., Biaou G.	Impact of mentoring on the likelihood of getting jobs in the agricultural sector in Benin	Development in Practice	1.2
40	Plant conservation biology	Houehanou T.D., Prinz K., Koua D., Hellwig F., Ebou A., Gouwakinnou G.N., Assogbadjo A.E., Glèlè Kakaï R., Zézé A.	Genetic diversity and population structure of a threatened tree species Afzelia africana Sm. ex Pers. among climatic zones for conservation challenges in Benin (West Africa)	Genetic Resources and Crop Evolution	2
41	Soil Sciences	Anago F.N., Agbangba E.C., Dagbenonbakin G.D., Amadji L.G.	Continuous assessment of cowpea [Vigna unguiculata L. Walp.] nutritional status using diagnosis and recommendation integrated system approach	Scientific Reports	4.6
42	Soil Sciences	Anago F.N., Agbangba E.C., Oussou B.C.T., Dagbénonbakin G.D., Amadji L.G.	Magnesium and zinc fertilisation improves rice yield and yield component responses to nitrogen, phosphorus, and potassium	South African Journal of Plant and Soil	2.1

A1.5. Scientific papers published in peer-review indexed journals WIF in 2023

N°	Disciplines	Authors' Names	Title of the article	Journals
1	Biostatistics	Gongnet E.E., Vihotogbé R., Affossogbe T., Glèlè Kakaï R.	Practical considerations on data patterns in Bayesian Maximum Entropy Estimation: A systematic and critical review	Journal of Applied Biosciences
2	Quantitative ethnobotany	Ahoyo C.C., Salako K.V., Houéhanou T.D., Montcho I., Glèlè Kakaï R.L., Houinato M.R.B.	Sociodemographic, environmental, and biological factors affecting uses of plants from open ecosystems: Insights for improved livelihoods and biodiversity conservation	Frontiers in Conservation Science
3	Natural Resources Management	Bourobou Bourobou J.A., Fandohan A.B., Glèlè Kakaï R.	Inhomogeneous Spatial Point Process Models for Species Distribution Analysis: A Systematic Review	Applications of Modelling and Simulation
4	Climate change and agriculture	Wabi M. A., Vanhove W., Idohou R., Hounkpèvi A., Glèlè Kakaï R., Van Damme P.	Détermination des dates favorables aux semailles du riz pluvial au Bénin par simulation mathématique des probabilités de survenue des séquences sèches	Research Application Summary
5	Biostatistics	Mugumaarhahama Y., Fandohan A.B., Glèlè Kakaï R.L.	Performance of inhomogeneous Poisson point process models under different scenarios of uncertainty in species presence-only data	Environmental Systems Research

N°	Disciplines	Authors' Names	Title of the article	Journals
6	Artificial intelligence	Houetohossou S.C.A., Houndji V.R., Hounmenou C.G., Sikirou R., Glèlè Kakaï R.	Deep learning methods for biotic and abiotic stresses detection and classification in fruits and vegetables: State of the art and perspectives	Artificial Intelligence in Agriculture
7	Natural Resources Management	Trekpo P., Houenon G.H.A., Hounsou-Dindin G., Natta A.K., Adomou A.C., Kokou K.	Current knowledge and conservation perspectives of *Detarium senegalense*, a vulnerable species in Africa	Revue Marocaine des Sciences Agronomiques et Vétérinaires
8	Biostatistics	Mba R.B., Lokonon B.E., Glèlè Kakaï R.	Quality report of infectious disease modeling techniques for point-referenced spatial data: A Systematic review	African Journal of Applied Statistics
9	Biostatistics	Orounla B.R., Sode A.I, Salako K.V., Glèlè Kakaï R.	Empirical Performance of CART, C5.0 and Random Forest Classification Algorithms for Decision Trees	African Journal of Applied Statistics
10	Biostatistics	Dete H.C., Senou M., Kossi G.E., Glèlè Kakaï R.	Model selection criteria for survival data based on Kullback's divergence: A systematic and critical review	Afrika Statistika
11	Natural Resources Management	Gebremedhn H.H., Dejene S.W., Tuffa S., Tesfay Y., Mensah S., Devenish A.J.M.	The dynamics of vegetation diversity and biomass under traditional grazing in Ethiopia's Somali rangeland	Plant-Environment Interactions
12	Floriculture	Deguenon M.P.P., Gbesso G.H.F., Idohou R., Hounsou-Dindin G., Djossa A.B.	Challenges and opportunities existing in the floriculture industry in Africa: knowledge and future research prospects	Journal of Biological Research & Biotechnology
13	Biostatistics	Traore K., Houenou D.F., Glèlè Kakaï R.	Analytical Insights of the Effects of Non-Pharmaceutical Interventions on SARSCoV-2 Dynamic with Application to West African Data	Contemporary Mathematics
14	Ecology	Trekpo P., Hounsou-Dindin G., Issiako D., Adomou A.C., Kokou K.	Caractéristiques structurales et dendrométriques des peuplements ligneux à *Detarium senegalense* J. F. Gmel dans le Dahomey Gap en Afrique de l'Ouest	Afrique Science

A1.6. Scientific papers published in non-indexed peer-review journals in 2023

N°	Disciplines	Authors' Names	Title of the article	Journals
1	Quantitative ethnobotany	Akakpo D.M.A., Pedanou C.L.E., Donou-Hounsode M., Assogbadjo A.E., Agbangla C.	Usages et importance socio-économique du dattier du désert *Balanites aegyptiaca* (L.) Delile. au Bénin	Bulletin de la Recherche Agronomique du Bénin
2	Agroforestry	Padonou E.A., Gbesso G.H.F., Akakpo A.B., Adjovi R., Akabassi G., Kolawole M.A.	Germination et croissance des types morphologiques de propagules du Palétuvier rouge (*Rhizophora racemosa*) du Site Ramsar 1017 au Bénin	Annales de l'Université de Parakou Série Sciences Naturelles et Agronomie
3	Ecology	Deguenonvo T.A.G., Houehanou T.D, Idohou R., Gouwakinnou G.N., Natta A.	Le cèdre des zones sèches (*Pseudocedrela kotschyi*) : état des connaissances et perspectives sur sa biologie de conservation (revue systématique)	Annales de l'Université de Parakou, Série Sciences Naturelles Agronomie

A1.7. Books and book chapters in 2023

N°	Field of research	Authors' Name	Title	References
1	Natural Resources Management	Salako K.V., Zanvo M.G.S., Sinsin B.C., Gnansounou S.C., Adomou C.A., Glèlè Kakaï R.	Atlas des espèces végétales de la mangrove du Bénin : Diversité, Usages, et Conservation	Salako K.V., Zanvo M.G.S., Sinsin B.C., Gnansounou S.C., Adomou C.A., Glèlè Kakaï R. (2023). Atlas des espèces végétales de la mangrove du Bénin : Diversité, Usages, et Conservation. Laboratoire de Biomathématiques et d'Estimations Forestières. 61p.
2	Agroforestry	Assogbadjo A.E., Hounkpèvi A., Salako K.V., Chadaré F.J., Idohou R., Gbèdomon R.C., Glèlè Kakaï R.	Scaling up African baobab food products valuation through enhancement of their safety and value chains for food and nutritional security in Benin, West-Africa	Assogbadj A.E., Hounkpèvi A., Salako K.V., Chadaré F.J., Idohou R., Gbèdomon R.C., Glèlè Kakaï R. (2023). Scaling up African baobab food products valuation through enhancement of their safety and value chains for food and nutritional security in Benin, West-Africa. Anthony Egeru, Megan Lindow, Kay Muir Leresche (ed). 2023. University Engagement with Farming Communities in Africa. https://doi.org/10.4324/9781003387497
3	Natural Resources Management	Lokonon B.E.	Assessment of the Impact of COVID-19 on Sustainable Forest Management in West Africa: cases of Benin, Côte d'Ivoire and Ghana	Lokonon B.E. (2023). Assessment of the Impact of COVID-19 on Sustainable Forest Management in West Africa: cases of Benin, Côte d'Ivoire and Ghana. Laboratoire de Biomathématiques et d'Estimations Forestières, University of Abomey-Calavi, Benin. https://hal.science/hal-04126547

A1.8. Participation to conferences/seminars/workshops in 2023

N°	Title, Place and periode of the conference/seminar	Type of Presentation (oral, poster, ..)	Attendee
1	Use and socio-economic values of *Ricinodendron heudelotii* (Bail.) Pierre, a wild oil species in Benin. 8e édition du Colloque des Sciences, Cultures et Technologies, Université d'Abomey-Calavi, Bénin, 25-29, September 2023	Oral	Guillaume Hounsou-Dindin
2	Les applications de l'industrie géospatiale dans l'agriculture et l'environnement, Symposium International sur la Robotique et l'Analyse Géospatiale en Afrique (SIRAGA). Sèmè-City, Cadjehoun – Cotonou, Bénin, 30-31 May 2023	Oral	Agbangba C.E.
3	Performance des algorithmes de modélisation de niche écologique et prédiction spatio- temporelle des aires de distribution de Cocos nucifera dans le Sud-Benin. Colloque International de Mathématiques, Informatique et Applications, 28-29 juillet 2023, Université Norbert-Zongo, Burkina-Faso, 28-29 July 2023	Oral	Agbangba C.E.
4	Climate action for smart Agrifood Systems under a One-Health approach: strengthening academia capacity in Benin. Golden Tulip Le Diplomate, Cotonou, Benin, 25-29 september 2023	Oral	Agbangba C.E.
5	The concurrent impacts of drought and leaf harvesting on two traditional African vegetable non-timber forest product species. 19th International Conference of Women Engineers and Scientists (ICWES19), Aotea Center, Auckland, New Zealand, 3-6 September 2023	Oral	
6	Agent Based Modeling course. Organized by Pro-RUWA project, Benin, 7-12 December 2023	Oral	Agounde G., Hounkpevi A.
7	Assessing present and future suitability for cultivation areas of *Moringa oleifera* Lam. in West Africa under a changing climate using analytical hierarchical process modelling. Science for Sustainable Livelihoods - Interdisciplinary Forum on Research-Based Approaches for Climate Resilience, Mittweida, Germany, 12-16 June 2023	Oral	Gandji K.
8	Strengthening Capacity in Biostatistics in West and Central Africa through dynamic Networking and Collaborations (Hybrid 3-day workshop). Hotel PARADISIA, Abomey-Calavi, Benin, 18 – 20 December 2023	Oral	Glèlè Kakai R.
9	Strengthening Capacity in Biostatistics in West and Central Africa through dynamic Networking and Colaborations, (Hybrid 3-day workshop). Hotel PARADISIA, Abomey-Calavi, Benin, 18 – 20 December 2023	Poster	Doumate J.
10	Nonlinear Mixed Models and related approaches in Infectious disease modeling: A systematic and critical review, Infectious Disease Modelling. Atelier de formation sur les droits de propriété intellectuelle et les autres formes de valorisation des résultats de recherche et de l'innovation. Benin, 30 January – 10 February 2023	Oral	Adeoti O. M.
11	Nonlinear Mixed Models and related approaches in Infectious disease modeling: A systematic and critical review, Infectious Disease Modelling. Journée Scientifique (UFR) Sciences Appliquées et Technologie sur Sciences et technologies au service du développement. Senegal, 11-13 May 2023	Poster	Adeoti O. M.
12	Nonlinear Mixed Models and related approaches in Infectious disease modeling: A systematic and critical review, Infectious Disease Modelling. 18th Biennial Sub Sahara African Network of the International Biometric Society (SUSAN IBS) Conference on "Human and Environment Interactions: The role of Biometry", Ghana, 10- 15 September 2023	Oral	Adeoti O. M.
13	Nonlinear Mixed Models and related approaches in Infectious disease modeling: A systematic and critical review, Infectious Disease Modelling. IIème Atelier des Doctoriales UAC-2023, Benin, 28-29 September 2023	Oral	Adeoti O. M.

14	Nonlinear Mixed Models and related approaches in Infectious disease modeling: A systematic and critical review, Infectious Disease Modelling. Workshop on "Strengthening Capacity in Biostatistics in West and Central Africa through Dynamic Networking and Collaborations", Hotel PARADISIA, Abomey-Calavi, Benin, 18 – 20 December 2023	Poster	Adeoti O. M.
15	VIIIe Colloque des Sciences, Cultures et Technologie de l'Université d'Abomey-Calavi/2ème Edition des Doctoriales Multidisciplinaires de l'UAC, Benin, 25-29 September 2023	Oral	Ahlonsou Ceptime Galilée
16	Citoyenne pour le Climat et la Biodiversité au Bénin, Benin, 9 December 2023	Oral	
17	Geospatial Analytics with R. Rwanda, November 2023	Oral	
18	Nutrition et qualité des aliments dans un contexte d'insécurité alimentaire quels défis pour le Niger? Niger, 02-23 February 2023	Oral	Daï E.H.
19	Femme et recherche pour le développement. Burkina-Faso, 28 March 2023	Oral	Daï E.H.
20	La valorisation des savoirs endogènes, gage de développement durable. Benin, 25-29 September 2023	Oral	Daï E.H.
21	Gestion durable de la biodiversité et changement environnementaux. Burkina-Faso, 20-22 September 2023	Oral	Daï E.H.
22	Festival Mangal: the first West African Festival on mangroves. Toubacouta, Senegal, 22 November – 2 December 2023.	Oral	
23	Optimisation of ML techniques for maize yield prediction under weather and fertilizer patterns. Benin, September 2023	Oral	Souand P.G. TAHI
24	Identifying fine climatic parameters for high maize yield using pattern mining: case study from Benin (West Africa). Ghana, 3-9 September 2023	Oral	Souand P.G. TAHI
25	An experimental analysis of machine learning algorithms for maize yield prediction. Ghana, 3-9 September 2023	Poster	Souand P.G. TAHI
26	Finding optimum climatic parameters for high tomato yield in Benin (West Africa) using frequent pattern growth algorithm. Deep Learning Indaba, Ghana, 3-9 September 2023	Poster	Houetohossou A.
27	Architectural and parametric optimization of pre-trained Convolutional Neural Network (CNN) with application on stress detection on tomato plants under climate and infection based simulated environments. AI4D Africa Scholarship - Scientific conference, Ethiopia, 11-13 December 2023	Oral	Houetohossou A.
28	Germany Alumni Expert seminar. Ghana, 22-26 October 2023	Oral	Houetohossou A.
29	Sprouting trials, different substrates and mineral fertilizers effect on growth parameters of *Parkia biglobosa* (Jacq) G. Don in Benin. 5ème colloque scientifique international pluri, inter, et transdisciplinaire de l'Université de Kara (UK): « Développement inclusif de l'Afrique de l'ouest à la croisée des méga tendances mondiales: Quels défis pour les Plans nationaux de développement ». Kara, Togo, 11-15 September 2023	Oral	Akakpo A.
30	Modelling suitable habitats for three native agroforestry species under the Representative Concentration Pathways (RCP) 4.5 and (RCP) 8.5 scenarios in Benin: evaluation of five models. Actes du colloque scientifique international en hommage au Professeur Sita GUINKO: Gestion durable de la biodiversité et changements environnementaux, Ouagadougou, Burkina Faso, 20-22 September 2023	Oral	Akakpo A.
31	Agroforestry tree species' diversity, density, uses, and their potential as biofertilizers in Central Benin. Actes du colloque scientifique international en hommage au Professeur Sita GUINKO: Gestion durable de la biodiversité et changements environnementaux, Ouagadougou, Burkina Faso, 20-22 September 2023	Poster	Akakpo A.
32	Diversity of hydraulic responses to water deficit and associated root traits in a panel of major crops and trees in controlled conditions and natural habitats. ELI Day, Belgium, May 2023	Poster	Kolawole M. A.
33	Human and environment interactions: The rôle of Biometry. 18th IBS SUSAN Conference at Kwame Nkrumah University of Science and Technology, Ghana, 11-15 September 2023	Oral	

34	Valorisation des savoirs endogènes, gage d'un développement durable. International conference organized by University of Abomey-Calavi, Benin, 25-29 September 2023	Oral	
35	Conference on Mathematics and its Application. Organized by AIMS Ghana, 27-30 November 2023	Oral	
36	Deep Learning Indaba 2023, held at the University of Ghana, Accra, from 3-9 September 2023	Poster	

APPENDIX 2.

Abstracts of published scientific papers in peer-review journals in 2023

Practical considerations on data patterns in Bayesian Maximum Entropy Estimation: A systematic and critical review

Gongnet E.E., Vihotogbé R., Affossogbe T., Glèlè Kakaï R.

Journal of Applied Biosciences, 181, 18877–18890
DOI: https://doi.org/10.35759/JABs.181.1

It is well known that some data features (sample size, skewness, among others) may determine method performance. The choice of those features depends on the researcher's level of awareness on the statistical method. In this study, the level of awareness on the influence of spatial data key characteristics (sample size, skewness, spatial dependency and variogram model) in Bayesian Maximum Entropy (BME) was analyzed. A systematic review was conducted that covers the period from 1990 (year of BME introduction) to 2019. Two main keywords "Bayesian Maximum Entropy" and "BME" were used for literature search. Publications which only mentioned the keywords without applying BME were excluded while those with application and/or BME theory discussion were considered. Six of the world's leading Open Access sources of scientific literature were considered, namely: Science Direct, African Journals Online, Springer, Google Scholar, MPDI and Academic Journals. A total of 118 research articles from 62 journals were identified. The sample sizes screened shows that 25.4% of the published articles used few samples (less than 100), which implies the variogram might not yield accurate results. The analysis of the use of skewness showed that most researchers do not apply transformation on skewed data (82.2%) nor consider skewness in their descriptive statistics (90.7%). Even though 11% of theoretical papers have mentioned about spatial dependency level, 92.4% of them failed to consider it. Most researchers (68.64%) do not specify the variogram models but when they do, they mostly use exponential model (12.7%). It clearly appears in this review that most researchers do not consider the effect of sample size, skewness, and spatial dependency level when applying BME. Yet very few research works have focused on these aspects. This therefore calls for more in-depth studies on the effect of data characteristics on BME's performance.

Keywords: Bayesian Maximum Entropy, sample size, skewness, spatial dependency

Modelling the current and future distribution of *Caesalpinia bonduc* (L.) Roxb: Its implication for future conservation of the species in the Southern Benin

Lokonon B.E., Gbemavo C.D.S.J.., Agounde G., Simbo D., Samson R., Glèlè Kakaï R.

African Journal of Ecology, 61(2), 389-398
DOI: https://doi.org/10.1111/aje.13122

Caesalpinia bonduc (L.) Roxb, the most commercialised medicinal species in Southern Benin, is reported to be extinct in the wild due to anthropogenic pressures on its natural habitats. Remaining individuals can only be found in traditional agroforestry systems and home gardens. It is therefore important to understand how spatio-temporal distribution of the species could be impacted by changing environmental conditions and propose strategies to be used for its conservation. Maximum Entropy (MaxEnt) modelling technique was used for modelling the current and future distribution of the species using present-day combined with two future forecast scenarios (Representative Concentration Pathways-RCP): low-RCP4.5 and high-RCP8.5 emission scenarios. Environmental and demographic factors have impacted the distribution of the species. Rainfall driest quarter (44.5%), population density (30.4%), rainfall driest month (14.7%), potential evapotranspiration (6.5%) and number of dry months (4%) mostly contributed to the model. High suitable areas of the species will increase about (2.28%) and (0.06%) with the RCP8.5 and RCP4.5, respectively, at horizon 2055. In contrast, less suitable areas will decrease about 3.11% (RCP4.5) and 1.71% (RCP8.5). In-situ conservation strategy is suggested to restore the species in the wild considering suitable areas for its growth, development and reproduction. Circa-situ conservation should be promoted in agroforestry systems and home gardens for sustainable use of the species.

Keywords: Benin, *Caesalpinia bonduc*, conservation, ecological niche modelling, endangered species

Modeling current and future distribution patterns of *Uvaria chamae* in Benin (West Africa): Challenges and opportunities for its sustainable management

Daï E.H., Houndonougbo J.S.H., Idohou R., Ouédraogo A., Glèlè Kakaï R., Hôtes S., Assogbadjo A.E.

Heliyon, 9(2), e13658
DOI: https://doi.org/10.1016/j.heliyon.2023.e13658

Uvaria chamae is a wild shrub species widely used as a source for traditional medicine, food and fuel in West Africa. The species is threatened by uncontrolled harvesting of its roots for pharmaceutical applications and by the extension of agricultural land. This study assessed the role of environmental variables for the current distribution and the potential impact of climate change on the future spatial distribution of U. chamae in Benin. We used data related to climate, soil, topography and land cover to model the distribution of the species. Occurrence data were combined with six least correlated bioclimatic variables derived from the WorldClim database, data on soil layers (texture and pH) and topography (slope) obtained from the FAO world database and land cover from the DIVA-GIS site. Random Forest (RF), Generalized Additive Models (GAM), Generalized Linear Models (GLM) and the Maximum Entropy (MaxEnt) algorithm were used to predict the current and future (2050–2070) distribution of the species. Two climate change scenarios (SSP245 and SSP585) were considered for the future predictions. The results showed that climate (i.e., water availability) and soil type are the key predictors of the distribution of the species. Based on future climate projections, RF, GLM and GAM models predict that the Guinean-Congolian and Sudano-Guinean zones of Benin will remain suitable for U. chamae, while it will decline in these zones according to the MaxEnt model. These results call for a timely management effort for the species in Benin through its introduction into agroforestry systems to ensure the continuity of its ecosystem services.

Keywords: Climate conditions, Ecological niche modeling, Ecosystem services, Wild edible plant

Sociodemographic, environmental and biological factors affecting uses of plants from open ecosystems: Insights for improved livelihoods and biodiversity conservation

Ahoyo C.C., Salako K.V., Houéhanou T.D., Montcho I., Glèlè Kakaï R., Houinato M.R.B.

Frontiers in Conservation Science, 4, 1127567
DOI: https://doi.org/10.3389/fcosc.2023.1127567

The sustainable management of open ecosystems requires the committed participation of the neighboring people. Attention should be given to plant species ecology, which conditions the rate of vegetation growth. Sociocultural and ecological factors contribute to both the loss and the conservation of fragile ecosystems. Owing to the importance of traditional medicine in Benin, a focus has been made on the selection of species in this field as a case study for highlighting the factors that drive the selection of plant species in Benin. Further inferences highlight the conservation status of the selected woodlands and savannas. The study assessed the effects of people's sociodemographic status and species' ecological parameters on the variation in people's knowledge associated with species' usefulness in traditional medicine in Benin. An ethnobotanical survey was conducted through semi-structured individual interviews with 590 specialists in traditional medicine. A conditional inference tree model was combined with a generalized linear model to determine the factors associated with traditional medicinal knowledge (TMK). It was found that TMK varied with informant ethnicity, source of knowledge, membership position, age, instruction level, and professional activity. As for the ecological and species accessibility factors, phytodistrict, mode of reproduction of the species, reasons for the species' disappearance, availability, and conservation status influenced TMK. When combining the two categories of factors, phytodistrict, habitat of species conservation, source of knowledge, and membership position of the informants were highlighted as the principal factors that influenced TMK. These identified factors should be integrated into a comprehensive management plan for TMK conservation and biodiversity management, and the sustainable use of savanna resources. Through this, sustainable management of open ecosystems, resulting in biodiversity conservation, livelihood improvement, and climate change mitigation, will be achieved. Such a plan should be based on the mix of ethnicities and the diversity of the species' habitat in each phytodistrict.

Keywords: open ecosystems management, traditional medicine, knowledge source, phytodistrict, species availability

Intensity and lag-time of non-pharmaceutical interventions on COVID-19 dynamics in German hospitals

Montcho Y., Klingler P., Lokonon B.E., Tovissodé C.F., Glèlè Kakaï R., Wolkewitz M.

Frontiers in Public Health, 11, 1087580
DOI: https://doi.org/10.3389/fpubh.2023.1087580

Evaluating the potential effects of non-pharmaceutical interventions (NPIs) on COVID-19 dynamics is challenging and controversially discussed in the literature. The reasons are manifold, and some of them are as follows. First, interventions are strongly correlated, making a specific contribution difficult to disentangle; second, time trends (including SARS-CoV-2 variants, vaccination coverage, and Q16 seasonality) influence the potential effects; third, interventions influence the different populations and dynamics with a time delay. In this article, we apply a distributed lag linear model on COVID-19 data from Germany from January 2020 to June 2022 to study intensity and lag time effects on the number of hospital patients and the number of prevalent intensive care patients diagnosed with polymerase chain reaction tests. We further discuss how the findings depend on the complexity of accounting for the seasonal trends. Our findings show that the first reducing effect of non-pharmaceutical interventions on the number of prevalent intensive care patients before vaccination can be expected not before a time lag of 5 days; the main effect is after a time lag of 10–15 days. In general, we denote that the number of hospital and prevalent intensive care patients decrease with an increase in the overall non-pharmaceutical interventions intensity with a time lag of 9 and 10 days. Finally, we emphasize a clear interpretation of the findings noting that a causal conclusion is challenging due to the lack of a suitable experimental study design.

Keywords: lag-time effects, non-pharmaceutical interventions, distributed lag linear model, COVID-19 dynamics, Germany

Contribution of mangroves ecosystems to coastal communities' resilience towards climate change: a case study in southern Cote d'Ivoire

Kochoni B.I., Avakoudjo H.G.G., Kamelan T.M., Sinsin C.B.L., Kouamelan E.P.

GeoJournal, 88, 3935–3951
DOI: https://doi.org/10.1007/s10708-023-10845-2

Local communities' perception on how ecosystems such as mangroves contribute to their resilience to climate change is essential to effectively engage them in adaptation and mitigation actions. This study assessed the perceptions of coastal communities on climate change, and the contribution of mangroves in their resilience to climate change in the southern Côte d'Ivoire. Individual interviews (n=120) were conducted in four coastal villages, selected based on their proximity to mangroves. Data were analyzed using the Chi-Square test simple correspondence analysis. Informants' knowledge on climate change was low. However, the scarcity of rainfall (62%), increased temperature (heat) (32%), and the high frequency of high winds (6%) have been cited as indicators of changes in the climate. More than half of respondents (63.3%) agreed that mangroves help people adapt to climate change because they produce more fish, shield people from poverty, and lessen flooding, storms, and erosion in their communities. This study has demonstrated a substantial relationship between the level of mangrove significance knowledge and the profession practiced in terms of whether it is affected by climate change. People with higher levels of education and members of particular professions frequently know more about climate change. The profession is a key driver in the knowledge of the contribution of mangroves in protecting fish fauna against climate change. Mangroves reduce the vulnerability of coastal communities to the effects of climate change through their ecosystem services which include fish productivity (which provides income to fishermen and fish sellers as well as alternative income to farmers), protection against flooding and erosion, and more. Therefore, it is of utmost importance to conserve this ecosystem at all costs.

Keywords: Perceptions, Resilience, Coastal communities, Climate change, Mangroves · Côte d'Ivoire

Influence of topography on the natural stand structure of *Boswellia dalzielii* Hutch. in a semi-arid environment: Insight into hill ecosystems conservation in Burkina Faso

Sabo P., Ouédraogo A., Lankoandé B., Salako K.V., Ouédraogo H., Glèlè Kakaï R.

Global Ecology and Conservation, 43, e02430
DOI: https://doi.org/10.1016/j.gecco.2023.e02430

As the dominant woody species of some hills, the conservation of *Boswellia dalzielii* Hutch. could contribute to preserve vegetation of these azonal ecosystems, but also to restore degraded ones. However, given the topographical variation in hills, understanding the effects of such variation on the stand structure of *B. dalzielii* can assist the sustainable management of the species and therefore that of the hills. This paper compared the floristic diversity and the population characteristics of *B. dalzielii* natural stands across four topographical units: eastern and western slopes, hilltops, and plains. Data were collected from 80 plots of 50 m × 30 m equally distributed among the four topographical units in natural stands of *B. dalzielii* across the Sudano-Sahelian zone of Burkina Faso. The topographical units were compared based on woody species diversity. Additionally, *B. dalzielii* trees density, stem diameter, slenderness coefficient and tree diameter and height size class distribution were compared among the topographical units. A total of 3481 trees representing 74 species distributed into 51 genera and 25 families were recorded. Woody species richness varied slightly but was higher on the plains (62 species) than on slopes (west: 50 and east: 53 species) and hilltops (55 species). The dissimilarity between the four units in terms of species composition was low (R = 0.161, p = 0.001). Trees density of *B. dalzielii* was two to eight times higher on eastern slopes (374.3 ± 255.5 trees/ha) than on hilltops (181.3 ± 118.7), western slopes (138.3 ± 132.2) and plains (45.0 ± 22.5). The largest trees were found on the western slopes (dbh = 27.4 ± 10.3 cm) while the smallest were found on the plains (dbh = 6.5 ±1.4 cm). About all trees found in the study area, the slenderness coefficient was < 75%, indicating low risk or susceptibility to windthrow. The stem diameter distribution exhibited a clear stable population of *B. dalzielii* in all units, but with recruitment difficulties. Our findings suggest that assisted natural regeneration actions are needed, especially in the plains and hilltops to assist the restoration of hills vegetation and to create refuge environments for biodiversity.

Keywords: Frankincense tree, Population structure, Sustainable management, Woody species diversity

Impact of climate patterns, land-use types and exploitation on the population structure of *Bombax costatum* Pellegr. and Vuillet in West African semi-arid savannas

Zerbo I., Salako K.V., Hounkpèvi A., Zozoda D., Glèlè Kakaï R., Thiombiano A.

Global Ecology and Conservation, 43, e02434
DOI: https://doi.org/10.1016/j.gecco.2023.e02434

Some multi-purpose woody species, although currently considered as "least concern" by the International Union for Conservation of Nature (IUCN), are undergoing several disturbances resulting from human overexploitation and changes in climate conditions and land-use types. The patterns of such disturbances are likely to vary across climate regions due to changes in socioecological context. However, they can strongly impair the long-term viability of species. Therefore, understanding the effects of such disturbances on populations of valuable species is essential for their sustainable management. This study examines the impact of climate regions, land-use types and exploitation (pruning and debarking) on the population ecology of *Bombax costatum*. Human exploitation indices (intensity of debarking and pruning) and ecological characteristics of the species (tree diameter, height, crown diameter and regeneration modes) were recorded in two contrasting climate regions (Sudanian and Sudano–Sahelian) and land-use types (protected area and unprotected area) in Burkina Faso. General linear models were used for data analysis. The results showed that at least two-thirds of individuals were debarked and pruned in the unprotected (66.17 ± 6.93%) and the protected area (73.61 ± 7.37%) of the Sudano–Sahelian climate region. Contrastingly, in the Sudanian climate region, 92.78 ± 3.89% of individuals were debarked and pruned in the unprotected area but only 15.56 ± 5.28% in the protected area. Although debarking was practised with low intensity (1–25%), pruning was severely and very severely practised (56–75% and 76–100%, respectively). The species displayed a similar tree diameter, crown diameter and total height between climate regions and land-use types except in the Sudanian unprotected area, where the highest values were observed. The climate regions did not significantly influence the densities of adult or juvenile individuals (p = 0.099). On the contrary, between protected to unprotected areas, there was an increase in the density of adults (p = 0.0080) and a decrease in that of juveniles (p =0.024). The diameter size classes distribution showed an unstable population in the protected area of the

Sudano–Sahelian climate region and the unprotected area of the Sudanian climate region indicating strong anthropogenic pressures. More than 60% of the regenerations were from root suckers, indicating that the species experienced poor sexual regeneration. In synthesis, our results showed that land use impacts varied between the two climate regions and that protected areas are not always a suitable place for the conservation of multi-purpose species. The results also suggested that *B. costatum* is threatened in West African semi-arid savanna and that there is an urgent need to implement proper management of the species and update its global conservation status.

Keywords: Climate, Conservation, Debarking, Declining, Land use, Pruning, Regeneration, Structural characteristics

Folk taxonomical distinction between *Irvingia gabonensis* and *I. wombolu* (Irvingiaceae) in the Volta Forest region, West Africa

Vihotogbé R., Avocèvou-Ayisso C., Djikpo R., Teka O., Sinsin B., Glèlè Kakaï R.

Biotechnology, Agronomy, Society and Environment, 27(1), 1-14
DOI: https://doi.org/10.25518/1780-4507.20096

Description of the subject: *Irvingia gabonensis* and *I. wombolu* produce edible kernels, with their fruit pulp tasting sweet and bitter, respectively. The overlap of their morphological and ecological traits creates taxonomic uncertainty.
Objectives: This study assessed the efficiency of folk classification system for the separation between *I. gabonensis* and *I. wombolu*, in the Volta Forest region (Togo), where both species co-occur.
Method: Interviews were conducted with 114 respondents of the five main sociolinguistic groups in the Volta Forest region, in order to identify distinctive traits between both species. Field reconnaissance and confirmation test were used to identify *I. gabonensis* and *I. wombolu* trees, which were evaluated against ecological features in folk classification system.
Results: Variations existed within each species but were not botanically delimited. The folk classification system was mostly based on fruit pulp taste and some ecological traits. Old local residents only trusted fruit taste to separate these species. Only young Akposso men additionally considered ecology and leaf shape in classification. The reconnaissance survey confirmed the consistency of their folk classification system. Dendrometric parameters of *I. gabonensis* depended on environmental factors, while land use system and soil geomorphology significantly influenced the occurrence of *I. wombolu*.
Conclusions: Fruit pulp taste and flowering seasons were widely used to distinguish between species, while young men used ecological and botanical features. This demonstrates their recent contact with these taxa. It is also likely that domestication is narrowing differences between *I. gabonensis* and *I. wombolu*.

Keywords: Domestication, taxonomy, species diversity, indigenous peoples' knowledge, biodiversity conservation

Seasonal variation of environment and conspecific density-dependence effects on early seedling growth of a tropical tree in semi-arid savannahs

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Understanding the mechanisms that facilitate species coexistence and maintain local species diversity in tree communities remains an important topic in community ecology. Among the proposed mechanisms, negative density dependence (NDD) theory predicts that seedling growth rate declines at high conspecific densities. However, local environmental conditions and seasonality may also modulate the strength of NDD. In this study, we used data from dry and wet seasons in West African semi-arid savannas to explore the importance of two mechanisms (NDD and environmental heterogeneity) in explaining variation in seedling growth of *Afzelia africana* Sm, a commercially important and threatened tree species in Africa. First, we investigated how seedling growth varied between dry and wet seasons, and between vegetation types (tree and shrub savannas). Second, we evaluated the effects of environmental heterogeneity (soil type, slope and elevation) and biotic factors (conspecific/heterospecific seedling and adult densities, leaf fungal infection, herbivory) on seedling growth in dry and wet seasons, while controlling for initial seedling size. We predicted that seedling growth would be higher in the wet than in the dry season, and in shrub savannas than in tree savannas due to varying stem density and intensity of competitive biotic interactions. We also hypothesized that slope and negative density dependence would affect seedling growth and that, the

density dependent effects would vary with environmental heterogeneity and seasonality. Results showed two distinct patterns of seedling growth primarily driven by seasonality: a higher growth rate in the wet season due to water availability and a smaller growth rate during the dry season, possibly because seedlings develop adaptation to drought and fire at the expense of their growth. Higher growth rate was also observed on flat and gentle slope. Density dependent effects on seedling growth were only observed with conspecific adults. Seasonality modulated the strength of the effect of conspecific adult density on seedling growth, which was significantly negative in the wet season and nonsignificant in the dry season. Our study provides insights that *A. africana* early seedling growth is modulated by interacting effects of seasonality, terrain slope and adult conspecific density. Campaigns for reforestation with *A. africana* in the semi-arid areas will require increased attention on the seedlings during the long periods of drought.

Keywords: *Afzelia Africana*, biotic neighborhood, conspecific adult density, dry season, negative density dependence, West Africa

Geographical distribution, abundance and population structure of *Ricinodendron heudelotii* (Baill.) Pierre ex. Heckel, a culturally important species in Benin Republic

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South African Journal of Botany, 157, 231-242
DOI: https://doi.org/10.1016/j.sajb.2023.03.062

Climate change and human activities pose a major threat to forest resources and the livelihoods of vulnerable communities. Understanding the factors that influence the distribution and abundance of priority species for these communities is crucial for conservation and sustainable management purposes. We identified the pedoclimatic and anthropogenic factors that influence the geographical distribution and abundance of *Ricinodendron heudelotii*, a woody species with high socio-cultural value in Benin, and assessed the demographic structure of its populations. Through a survey carried out in all phytodistricts of the Guineo-Congolian zone and the Sudano-Guinean transition zone of Benin, the species' presence was recorded with the help of the hunters and Fulani communities living in the area. We set thirty-eight plots of 1 ha (100 m£ 100 m) in forests where the largest populations of the species were found. Generalized linear mixed models were used to compare the mean abundance of the species between phytodistricts and to identify underlying factors shaping observed differences. Slope analysis of the ordinary least squares regression of tree density against diameter size class distribution midpoint and the skewness coefficient were used to assess the populations' structure of the species. The species is distributed in the phytodistrict within latitude 6° 50′ - 9° 50′. These phytodistricts are the most watered phytodistricts of Benin with rainfall between 900 mm and 1300 mm per year. The abundance of the species varied from one phytodistrict to another (from 9.25 § 2.39 to 19.5 § 4.5 trees. ha-1) and is significantly influenced by aridity index, moisture index of the arid quarter, harvest intensity, and wildfires. An assessment of the population structure revealed a predominance of small-diameter individuals, suggesting some population stability. Long-term conservation of the species requires controlling anthropogenic pressures on its populations.

Keywords: *Ricinodendron heudelotii*, Population ecology, Aridity index, Generalized linear mixed models, Anthropogenic pressure, West Africa

Assessing the Impact of Vaccination on the Dynamics of COVID-19 in Africa: A Mathematical Modeling Study

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DOI: https://doi.org/10.3390/vaccines11040857

Several effective COVID-19 vaccines are administered to combat the COVID-19 pandemic globally. In most African countries, there is a comparatively limited deployment of vaccination programs. In this work, we develop a mathematical compartmental model to assess the impact of vaccination programs on curtailing the burden of COVID-19 in eight African countries considering SARS-CoV-2 cumulative case data for each country for the third wave of the COVID-19 pandemic. The model stratifies the total population into two subgroups based on individual

vaccination status. We use the detection and death rates ratios between vaccinated and unvaccinated individuals to quantify the vaccine's effectiveness in reducing new COVID-19 infections and death, respectively. Additionally, we perform a numerical sensitivity analysis to assess the combined impact of vaccination and reduction in the SARS-CoV-2 transmission due to control measures on the control reproduction number (Rc). Our results reveal that on average, at least 60% of the population in each considered African country should be vaccinated to curtail the pandemic (lower the Rc below one). Moreover, lower values of Rc are possible even when there is a low (10%) or moderate (30%) reduction in the SARS-CoV-2 transmission rate due to NPIs. Combining vaccination programs with various levels of reduction in the transmission rate due to NPI aids in curtailing the pandemic. Additionally, this study shows that vaccination significantly reduces the severity of the disease and death rates despite low efficacy against COVID-19 infections. The African governments need to design vaccination strategies that increase vaccine uptake, such as an incentive-based approach.

Keywords: COVID-19; vaccination impact; compartmental model; reproduction number; Africa

An updated review of the African multipurpose tree species *Detarium senegalense* J.F.Gmel. (Fabaceae)

Dassou G.H., Favi G.A., Salako K.V., Ouachinou J.M.A.S, Trekpo P., Akouete P., Agounde G., Djidohokpin D., Dansi M., Kouyaté A.M., Natta A., Yedomonhan H., Adomou A.C.

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DOI: https://doi.org/10.1016/j.sajb.2023.04.035

Detarium senegalense J.F.Gmel. is a woody legume tree species native of Africa. It holds a wide spectrum of medicinal, nutritional, socio-ecological, and economic benefits. However, the growing regional trade around its fruits makes it a threatened and priority species for conservation. The current study was carried out to systematically review and document findings on the multiple benefits of *D. senegalense* and identify gaps and research avenues to sustain its uses and prevent its extirpation from natural ecosystems. Information related to the taxonomy, botanical description, distribution, ecology, traditional uses, phytochemistry and pharmacological activities was systematically collected using relevant keywords in various online databases (PROTA4U, Web of Science, PubMed, Google Scholar, Science Direct, Springer Online, Global Biodiversity Information Facility, and Research Gate) and books. A total of 104 papers from 1789 to 2021 were included in our review of which most (53%) focused on biochemistry, pharmacology, and traditional uses. The remaining scientific studies were found on ecology and distribution, population structure, germination, nutrient, and economical aspects. The main bioactive components namely alkaloids, tannins, flavonoids, terpenes (monoterpenes, triterpenoids, and sesquiterpenes), steroids, saponins, fatty acids, xyloglucanes, phenols, cyanogen glycoside, leucine, chlorophylls, and carotenoids were isolated from the different parts (stem bark, pulp of fruit, and seed) of the species. These compounds and extracts isolated show a wide range of protective activities including antidiabetic, antibacterial, antifungal, and anti-diarrheal. Fruits are a potent source of Vitamin C, and its content is 29, 12, 7 and 5 times that of orange, zest of lemon, guava, and baobab pulps, respectively. Unfortunately, some forms of the species fruits are toxic due to the presence of a cyanogenic glycoside derivative. Phytochemical and ethnopharmacological backgrounds of the species suggest potential usages as healthy foods and food supplements. However, due to the existing toxic forms, important care should be emphasized to ensure the safety and effective use of derived products of the species. Nevertheless, more investigations are still needed to properly engage the domestication process of the species in order to ensure its sustainable use.

Keywords: *Detarium senegalense*, Botanical notes, Traditional uses, Phytochemistry, Pharmacological effects

Lag-time effects of vaccination on SARS-CoV-2 dynamics in German hospitals and intensive-care units

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DOI: https://doi.org/10.3389/fpubh.2023.1085991

Background: The Efficacy and effectiveness of vaccination against SARS-CoV-2 have clearly been shown by randomized trials and observational studies. Despite these successes on the individual level, vaccination of the population is essential to relieving hospitals and intensive care units. In this context, understanding the effects of

vaccination and its lag-time on the population-level dynamics becomes necessary to adapt the vaccination campaigns and prepare for future pandemics.
Methods: This work applied a quasi-Poisson regression with a distributed lag linear model on German data from a scientific data platform to quantify the effects of vaccination and its lag times on the number of hospital and intensive care patients, adjusting for the influences of non-pharmaceutical interventions and their time trends. We separately evaluated the effects of the first, second and third doses administered in Germany.
Results: The results revealed a decrease in the number of hospital and intensive care patients for high vaccine coverage. The vaccination provides a significant protective effect when at least approximately 40% of people are vaccinated, whatever the dose considered. We also found a time-delayed effect of the vaccination. Indeed, the effect on the number of hospital patients is immediate for the first and second doses while for the third dose about 15 days are necessary to have a strong protective effect. Concerning the effect on the number of intensive care patients, a significant protective response was obtained after a lag time of about 15–20 days for the three doses. However, complex time trends, e.g. due to new variants, which are independent of vaccination make the detection of these findings challenging.
Conclusion: Our results provide additional information about the protective effects of vaccines against SARS-CoV-2; they are in line with previous findings and complement the individual-level evidence of clinical trials. Findings from this work could help public health authorities efficiently direct their actions against SARS-CoV-2 and be well-prepared for future pandemics.

Keywords: delayed effects, vaccination, non-pharmaceutical interventions (NPIs), linear lag models, COVID-19, policy decisions

Climate change effects on desert date *Balanites aegyptiaca* (L.) Delile in Benin: Implications for conservation and domestication

Hounsou-Dindin G., Idohou R., Donou-Hounsode M.T., Adomou A.C., Assogbadjo A.E., Glèlè Kakaï R.

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DOI: https://doi.org/10.1111/1477-8947.12285

Effectiveness of *Balanites aegyptiaca* conservation and sustainable exploitation requires a better knowledge of the intrinsic environmental factors linked with its current and future geographic distribution. This study aimed to map suitable areas for the conservation and domestication of *B. aegyptiaca* under present-day and future climate conditions in Benin. A total of 424 occurrence records of *B. aegyptiaca* were combined with the environmental variables of two climatic scenarios (optimistic RCP 4.5 and pessimistic RCP 8.5) following the biodiversity modeling approach (biomod2). Findings were that under current and future climate conditions (RCP 4.5 and 8.5), almost onethird of the country's area (protected and non-protected areas), mainly located in the semiarid zone, presents a high probability of suitable areas for the conservation and domestication of *B. aegyptiaca* by 2055-time horizon. Exceptionally, a fine portion of medium suitable area for its distribution was found in the coastal area. Whatever the future climatic scenarios, a probable potential extension of the suitable areas (2.52% for RCP 4.5 and 0.43% for RCP 8.5) will be noted, thus emphasizing a positive impact of climate changes on the species. These findings are timely and could be used for setting appropriate management policies targeting the species in Benin.

Keywords: biomod2, climate change, ecology, modeling, phytodistrict, wild oil species

Economic Valuation of Mangroves and a Linear Mixed Model-Assisted Framework for Identifying Its Main Drivers: A Case Study in Benin

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Mangroves are brackish wetland ecosystems found in tropical areas. They are highly productive ecosystems that contribute to the economic empowerment of local communities. Proper estimation of their monetary value and the extent of their contribution to rural households' income, although challenging, is paramount for sustainable management decisions. This study aimed to estimate the total economic wealth earned from mangrove ecosystems in Benin. Specifically, the study assessed the diversity of ecosystem services (ESs) provided by mangroves and the

contribution of Ess to the total annual economic value of mangroves, and it identified socio-demographic drivers of the total economic value at the individual informant level. In total, 298 informants from 15 villages were interviewed to determine the diversity of mangrove ESs. The ESs were then gathered per category. Household-level economic values of mangroves, economic values of mangroves per ES category, and total economic value were estimated by combining diverse approaches. The contribution of each category of ES to the total economic value (TEV) was determined. A Principal Component Analysis (PCA) was applied to describe the relationships between the economic value of categories of ESs. A Linear Mixed Effect Model (LMEM) was used to determine valid socio-demographic drivers of the TEV. Twenty-nine ESs were identified, with regulation and recreation services being the best contributors to annual TEV, which was estimated at USD 1.29 billion (USD 195,223.69/hectare). Stakeholdership followed by household size are the main socio-demographic drivers of TEV. The identified ESs and their estimated economic value can be incorporated into policy briefs and technical sheets to (i) promote ESs for the optimisation of TEV and (ii) raise awareness and funding for the conservation and sustainable management of mangrove ecosystems.

Keywords: mangroves; ecosystem services; economic value; climate negotiations; statistical models

Inhomogeneous Spatial Point Process Models for Species Distribution Analysis: A Systematic Review

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Applications Of Modelling and Simulation, 7, 49-62

This study aims to systematically review the application of inhomogeneous spatial point process models (ISPPMs) for species distribution analysis. The review focused on (i) the trend in the use of ISPPMs, (ii) the general characteristics of the studies reviewed, and (iii) the practice of inhomogeneous spatial point process modeling. Based on specific criteria, a search using Publish or Perish (PoP) software and Google Scholar databases was performed for published papers on ISPPMs from 2006 to 2020. The study revealed a significant evolution in the use of ISPPMs. Most of the studies were conducted at regional, national, and continental scales. More than 60% of the papers used presence-only data. The linear model was the most used (47.12%). Maximum likelihood (21%) and minimum contrast estimation (19%) were the primary methods for estimating the fitted model parameters. The goodness of fit, performance analysis and model comparison guided fitting model validation. Moreover, many of these studies (56.91%) did not explicitly address the issues of model specification and spatial dependence. Furthermore, 47% of the articles considered did not clarify the estimation method used. New challenges and perspectives are to be explored.

Keywords: Cox point process, Inhomogeneous point process, Inhomogeneous Poisson process, Markov point process, Spatial point process models

Détermination des dates favorables aux semailles du riz pluvial au Bénin par simulation mathématique des probabilités de survenue des séquences seches

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Research Application Summary, 19(1): 130-140

La baisse de la pluviométrie et l'irrégularité des pluies constituent des préoccupations majeures pour les producteurs de riz pluvial. Cette étude avait pour objectif d'analyser la variabilité des débuts et fins des pluies afin de déterminer les dates favorables aux semailles de riz pluvial au Centre et au Nord-Bénin. Pour ce faire, les données pluviométriques journalières au cours de la période 1970 à 2016 de trois stations pluviométriques situées à Malanville, Tanguiéta et Savè ont été collectées à l'Agence Météorologique du Bénin. La statistique descriptive et des analyses fréquentielles ont été utilisées pour analyser la variabilité des débuts et fins des pluies. Les probabilités de survenue des séquences sèches ont été calculées en utilisant la chaîne de Markov d'ordre 1. Les séquences sèches > 5, 7 et 10 jours ont été utilisées en phases végétative et reproductive en simulant des semis de riz pluvial réalisés tous les sept (7) jours. Il apparaît que la variabilité (15 à 29%) des débuts de pluies est plus forte que celle (2 à 5%) des dates de fin. A Tanguiéta, les dates favorables aux semailles du riz pluvial vont du 9 mai au 3 juillet alors qu'aucune date n'a été favorable aux semailles du riz pluvial à Glazoué et Malanville. Dans ces deux dernières localités, les séquences sèches (> 5 jours), préjudiciables à la floraison et compromettant la productivité du riz pluvial, ont présenté des probabilités très élevées (0,7 à 1). Les résultats renforcent la résilience des riziculteurs dans le choix

des dates favorables aux semis du riz pluvial et suggèrent que ces derniers courrent moins de risques en optant pour les variétés à cycle court < 100 jours.

Keywords: Chaîne de Markov, riz pluvial, séquences sèches, choix variétal, calendrier cultural

Explaining the Positioning of Agricultural Entrepreneurs on the Necessity-Opportunity Continuum in Sub-Saharan Africa: Insights from Benin

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Despite the potential of agriculture to reduce unemployment in sub-Saharan Africa, research on agricultural entrepreneurship is scarce, especially regarding the entrepreneurs' motivations. The aim of this research is to examine the intensity of necessity and opportunity motivations among agricultural entrepreneurs and the influence of socioeconomic characteristics, personality, and environmental factors. Hence, the study reports a survey of 819 agricultural entrepreneurs in Benin and uses multinomial logistic regressions. Most agricultural entrepreneurs are moderately necessity-driven (76%); the remainder includes highly necessity driven entrepreneurs (4%), moderately opportunity-driven entrepreneurs (6%), and highly opportunity-driven entrepreneurs (14%). Those displaying higher intensity of necessity motivations can be at any education level, are former employees, are less proactive, less optimistic, and operate in the services sector. In contrast, highly opportunity-driven entrepreneurs are likely to have received a university education and agricultural professional training, operate in the services sector, and have better access to finance and technologies. This study advances the push-pull theory by revealing a richer set of entrepreneurial motivations beyond the simplistic dichotomic view. Hence, policymakers could devise entrepreneurship strategies and programs that consider the diverse motivations of entrepreneurs and the influencing factors to move them toward increased opportunity entrepreneurship.

Keywords: Entrepreneurship, agriculture, motivation dichotomy, necessity, opportunity, Benin

Structural and taxonomic diversity predict above-ground biomass better than functional measures of maximum height in mixed-species forests

Mensah S., Noulèkoun F., Salako K.V., Lokossou C.J.M., Akouété P., Seifert T., Glèlè Kakaï R.

Applied Vegetation Science, 26(2), e12732
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Aims: Mixed-species forests are known to be highly productive systems because of their high species diversity, including taxonomic diversity (species richness) and structural diversity. Recent empirical evidence also points to plant maximum height, as a functional trait that potentially drives forest above-ground biomass (AGB). However, the interrelations between these biotic variables are complex, and it is not always predictable if structural diversity attributes or functional metrics of plant maximum height would act as the most important determinant of stand biomass. Here we evaluated the relative importance of structural diversity attributes and functional metrics of plant maximum height (Hmax) in predicting and mediating AGB response to variation in species richness in mixed-species forests, while also accounting for fine-scale environmental variation.
Location: Northern Benin.
Methods: We used forest inventory data from mixed-species stands of native and exotic species. We quantified structural diversity as coefficient of variation of tree diameter at breast height (CVdbh) and of height (CVHt). For plant Hmax, we computed three metrics: functional range (FRHmax), functional divergence (FDHmax) and community-weighted mean (CWMHmax). We used topographical variables such as elevation and slope to account for possible environmental effects. Simple and multiple mixed-effects models, and structural equation models were performed to assess the direct and indirect links of AGB with species richness through structural diversity attributes and functional metrics of plant Hmax.
Results: Species richness and CVdbh were positively related to AGB, while functional metrics of plant Hmax were not. Structural equation models revealed that species richness influenced AGB indirectly via CVdbh, which alone strongly promoted AGB. Elevation only had a positive direct effect on AGB. While increasing species richness

enhanced CVdbh and functional measures of plant Hmax, there was no support for the latter mediating the effects of species richness on AGB. Conclusion: Structural diversity has a significant advantage in predicting and mediating the positive effect of species richness on AGB more so than functional measures of plant Hmax. We argue that structural diversity acts as a mechanism for the species richness–AGB relationship, and that maintaining high structural diversity would enhance biomass in mixed-species forests.

Keywords: Benin, ecosystem functioning, plant maximum height, structural equation modeling, taxonomic diversity, tree size variation

Incorporating intraspecific variation into species distribution models improves climate change analyses of a widespread West African tree species (*Pterocarpus erinaceus* Poir, Fabaceae)

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Global Ecology and Conservation, 45, e02538
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Climate change is predicted to affect species distribution worldwide. Most of the methods used to evaluate such impact so far assume that species respond to the environmental gradients in a uniform way along their distribution range. Because populations occupying different niches may differ in their response to climate change due to local adaptation, accounting for intraspecific variation in species distribution models (SDMs) may yield more reliable predictions for widely distributed species. *Pterocarpus erinaceus* Poir is a highly valued but endangered tree species, which occurs in the Sudanian (SZ), Sudano-Guinean (SGZ) and Guinean (GZ) ecological zones of Benin. Here, we used two (whole-species and intraspecific-level) SDM approaches to evaluate how local adaptation, quantified through niche differentiation, influences the potential impact of climate change on the distribution of *P. erinaceus* in Benin. The maximum entropy (MaxEnt) algorithm was employed to simulate the current and future distributions of the species under various Shared Socioeconomic Pathways (SSPs) climate scenarios. The results showed three distinct populations of the species according to the ecological zones of Benin. The intraspecific populations displayed no niche overlap and thus were considered as locally adapted. Mean diurnal range was the main variable that determined the current distribution of the SZ population (percent contribution of 45.9%) while the distribution of the SGZ and GZ populations were determined by isothermality (percent contribution of 58.7% and 76.2%, respectively). While the whole-species SDMs showed that climate change would lead to significant reductions in the species suitable habitats in SZ under SSP2–4.5, SSP1–2.6, and SSP5–8.5, the SDMs based on intraspecific populations indicated a high decrease in habitat suitability in the GZ and an upward shift of the SGZ towards the SZ under the future climate scenarios. Our results suggest that incorporating intraspecific variation into SDMs improves predictions of the impact of climate change and helps to identify appropriate population-based conservation strategies.

Keywords: Climate change, Ecological niche modelling, Phenotypic plasticity, Niche conservatism, Benin

Digital soil mapping: a predictive performance assessment of spatial linear regression, Bayesian and ML-based models

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Modeling Earth Systems and Environment, 10, 595–618
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Nowadays, information on the spatial distribution of soil properties is considered a key element for environmental research and for agricultural planning and decision-making to monitor soil conditions, agricultural policies, etc. Developing models for spatial data is easy, but reliable predictions from such models are sometimes challenging due to the data features. Using simulation and data from the WoSI-ISRIC SoilGrid 250 m, we compared the predictive performance of five models: Spatial Linear Regression (SLR-REML), Machine learning (ML)-based models (Random Forest: RF and Random Forest Residual Kriging: RFRK), and Bayesian models (Integrated Laplace Approximation-Stochastic Partial Differential Equations: INLASPDE and spBAYES). Considering data characteristics such as spatial autocorrelation, range parameter, strength and type of relationship between the response variable and covariates, we cross-validated the models' results using the following criteria: precision, unbiasedness, and uncertainty (RMSE,

coefficient of determination (R^2), Lin's concordance coefficient (휌c), and predicted interval coverage probability (PICP)). The results revealed the high precision of SLR-REML with a small bias in the case of low spatial autocorrelation. ML models (RF and RFRK) stood by their ability to account for nonlinearities, particularly the flexibility of RFRK to handle high spatial autocorrelation. The INLA-SPDE model was robust to all data characteristics. Despite its drawbacks related to the computation time observed, the SLR-REML model relaxed the minimum limit about the number of observations required in the classical regression by linear mixed modeling (REML-LMM) to make better predictions in Digital Soil Mapping (DSM). In addition to commonly used machine learning (ML) techniques, INLASPDE and SLR could be suitable for the understanding, characterization and mapping through spatiotemporal modeling of soil properties and environmental variables.

Keywords: Spatial linear regression, Flexibility, Uncertainty, INLA-SPDE, RFRK, RF, DSM

Germination et croissance des types morphologiques de propagules du Palétuvier rouge (*Rhizophora racemosa*) du Site Ramsar 1017 au Bénin

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Annales de l'Université de Parakou Série Sciences Naturelles et Agronomie, 13(1), 65-76
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Rhizophora racemosa est une espèce de mangrove présente au Bénin. Elle est très vulnérable dans son biotope à cause de la pression des populations riveraines pour l'exploitation de son bois (énergie et service). Pour sa conservation, les essais des plantations enregistrent des échecs à cause de la qualité des plants utilisés. Cette étude évalue la germination et la croissance des propagules de *R. racemosa* provenant des populations de mangrove du site Ramsar 1017. 1200 propagules ont été collectées et mesurées suivant leur poids, longueur et épaisseur. Une Classification Ascendante Hiérarchique suivie de l'Analyse Canonique Discriminante ont permis de regrouper les propagules par type morphologique et de décrire les différences entre ces types morphologiques. Une analyse de variance sur mesures répétées a été effectuée sur les données de germination et de croissance en rapport avec les types morphologiques identifiés. Quatre types morphologiques (1, 2, 3 et 4) ont été décrits. Les types morphologiques 2 et 4 ont regroupé des individus à propagules longues et lourdes (en moyenne 29 cm et 35 g), présentant un taux de germination élevé (environ 80%) avec des plantules à croissance rapide. Les types morphologiques 1 et 3 ont regroupé des individus à propagules courtes et de faible poids (en moyenne 23 cm et 24 g), présentant un taux de germination faible (environ 65%) avec des plantules à croissance lente. Les types morphologiques 2 et 4 paraissent donc intéressants pour les stratégies de restauration des mangroves avec *R. racemosa* dans le site Ramsar 1017.

Keywords: Mangrove, Restauration, Morphotypes, Performances de croissance, Bénin.

Modeling the effects of Prophylactic behaviors on the spread of SARS-CoV-2 in West Africa

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Various general and individual measures have been implemented to limit the spread of SARS-CoV-2 since its emergence in China. Several phenomenological and mechanistic models have been developed to inform and guide health policy. Many of these models ignore opinions about certain control measures, although various opinions and attitudes can influence individual actions. To account for the effects of prophylactic opinions on disease dynamics and to avoid identifiability problems, we expand the SIR-Opinion model of Tyson et al. (2020) to take into account the partial detection of infected individuals in order to provide robust modeling of COVID-19 as well as degrees of adherence to prophylactic treatments, taking into account a hybrid modeling technique using Richard's model and the logistic model. Applying the approach to COVID-19 data from West Africa demonstrates that the more people with a strong prophylactic opinion, the smaller the final COVID-19 pandemic size. The influence of individuals on each other and from the media significantly influences the susceptible population and, thus, the dynamics of the disease. Thus, when considering the opinion of susceptible individuals to the disease, the view of the population at

baseline influences its dynamics. The results are expected to inform public policy in the context of emerging and re-emerging infectious diseases.

Keywords: COVID-19; Opinion; Hybrid modeling; Reproduction number; Richard's model; Africa

Performance of inhomogeneous Poisson point process models under different scenarios of uncertainty in species presence-only data

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Haphazard and opportunistic species occurrence (PO) data are widely used in species distribution models (SDMs) instead of high-quality species data gathered using appropriate and structured sampling methods, which is expensive and often spatially limited. Despite their widespread use in ecology, PO data are prone to errors and uncertainties, such as imperfect detectability, positional imprecision, and spatial niche truncation, which make their use analytically challenging for effective and adaptive biodiversity management and conservation. Using simulated data, this study investigates the effects of these uncertainties on the performance of spatial point process-based presence-only and integrated SDMs. We investigated three SDMs in this study, one that ignores imperfect detectability: the presence-only model (PO model), and two that account for it: the thinned presence-only model (THINPO model) and the integrated model (PBPC model). The ability of these SDMs to produce accurate maximum likelihood estimates of intensity model coefficients and reliable predictions of species distributions under different data quality scenarios was investigated. The results show that SDMs that account for imperfect detectability (THINPO or PBPC models) are not applicable in situations of high detectability. In this situation, the PO model produces the most accurate maximum likelihood estimates of the models' coefficients ($\beta_{\cdot k}$), and consequently the most accurate predictions of species distributions ($\hat{}$(s)). The effects of positional uncertainty and spatial niche truncation on this SDM output are minimal. However, in situations of low detectability, it is preferable to use the PBPC model. Positional uncertainty and spatial niche truncation have negligible effects on the output of this SDM, except when positionally uncertain PO data are analyzed along with truncated PC data. These minimal effects of spatial niche truncation on SDM outputs demonstrate the transferability of SDMs. However, the effects of all these uncertainties may depend on the characteristics of the species. Prior to modeling species distributions, a multivariate environmental similarity surface analysis should be performed to test the similarity between data from the restricted region to be used for model calibration and data from the entire range. If this analysis reveals dissimilarities, larger spatial and ecological scales should be considered to address the issue of spatial niche truncation. Further efforts could address the effects of species characteristics on SDMs performance and assess the effects of species-specific uncertainties.

Keywords: Imperfect detection, Sampling bias, Positional uncertainty, Species distribution models, Poisson point process, Data integration, Data simulation

Usages et importance socio-économique du dattier du désert *Balanites aegyptiaca* (L.) Delile. au Bénin

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Bulletin de la Recherche Agronomique du Bénin (BRAB), 33(2), 39-55

La connaissance des usages locaux et de l'importance socio-économique d'une ressource est essentielle pour sa gestion durable. L'étude a porté sur *Balanites aegyptiaca*, un fruitier sauvage négligé et sous-utilisé au Bénin, et distribué principalement dans la zone phytogéographique soudanienne. L'objectif était de documenter les connaissances locales sur les utilisations de l'espèce ainsi que son importance socio-économique pour les populations locales en lien avec les groupes ethniques, l'âge, le sexe, et le phytodistrict. Les données ont été collectées à travers des entretiens individuels semistructurés auprès de 461 personnes sélectionnées suivant un échantillonnage aléatoire. Les données collectées portaient sur les usages, l'importance des catégories d'usage (échelle de Likert) et la perception locale sur la dynamique temporelle des peuplements naturels de l'espèce. Au total les 136 usages spécifiques suivants ont été cités : médicinaux (87) ; alimentaires (12) ; cosmétiques (7) ; commerciaux (5) ; artisanaux (4) ; fourrage (2) ; autres catégories (19). Les usages alimentaires (2,38 ± 0,06) et médicinaux (1,80 ± 0,09) ont été les plus cités. La valeur d'usage et l'indice de valeur d'importance ont varié

significativement ($p < 0.05$) entre les groupes socioculturels ou sociolinguistiques, les classes d'âge et les phytodistricts, mais pas entre les sexes. Les adultes et les vieux détiennent plus de connaissances que les jeunes. L'importance socio-économique était plus avérée pour les groupes ethniques du phytodistrict Mékrou-Pendjari Est où la valeur d'usage et l'indice de valeur d'importance étaient les plus élevés. L'espèce a connu une dynamique régressive et les principales causes sont l'agriculture (66,59%) et le pâturage (17,06%). L'étude fournit des informations préliminaires pour la domestication de *Balanites aegyptiaca* au Bénin.

Keywords: Plante oléagineuse, ethnobotanique, dynamique, valeur d'usage, valorisation

Climate and soil effects on tree species diversity and aboveground carbon patterns in semi-arid tree savannas

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Climatic and edaphic effects are increasingly being discussed in the context of biodiversity-ecosystem functioning. Here we use data from West African semi-arid tree savannas and contrasting climatic conditions (lower vs. higher mean annual precipitation-MAP and mean annual temperature-MAT) to (1) determine how climate modulates the effects of species richness on aboveground carbon (AGC); (2) explore how species richness and AGC relate with soil variables in these contrasting climatic conditions; and (3) assess how climate and soil influence directly, and/or indirectly AGC through species richness and stand structural attributes such as tree density and size variation. We find that greater species richness is generally associated with higher AGC, but more strongly in areas with higher MAP, which also have greater stem density. There is a climate-related influence of soils on AGC, which decreases from lower to higher MAP conditions. Variance partitioning analyses and structural equation modelling show that, across all sites, MAP, relative to soils, has smaller effect on AGC, mediated by stand structural attributes whereas soil texture and fertility explain 14% of variations in AGC and influence AGC directly and indirectly via species richness and stand structural attributes. Our results highlight coordinated effects of climate and soils on AGC, which operated primarily via the mediation role of species diversity and stand structures.

Tree height-diameter, aboveground and belowground biomass allometries for two West African mangrove species

Zanvo S.M.G., Mensah S., Salako K.V., Glèlè Kakaï R.
Biomass and Bioenergy, 176, 106917
DOI: https://doi.org/10.1016/j.biombioe.2023.106917

Accurate estimation of biomass and carbon stocks in mangrove forests is a prerequisite for a better understanding of their role in climate regulation. Allometric equations remain appropriate tools in this context but are lacking for many mangrove species and sites across Africa. In this study, we destructively sampled 68 individual trees of the two dominant West African mangrove species (*Rhizophora racemosa* and *Avicennia germinans*) to (i) determine species-specific height-diameter allometry; (ii) evaluate biomass allocation to stem, branches, leaves and roots components; (iii) establish species-specific aboveground-, belowground- and total biomass allometric equations; and (iv) examine the accuracy of our best biomass model against existing equations for mangroves. Diameter at breast height (Dbh), total height (H), wood density and crown diameter were used as predictors in the models. Results showed that Dbh explained 53% and 62% of height variation for *R. racemosa* and *A. germinans*, respectively. Stems stored the highest biomass fractions (84.30% for *R. racemosa* and 52.80% for *A. germinans*), followed by branches, while the belowground compartment contributed to 19%–22% of the total biomass. Among the candidate biomass models, the models incorporating Dbh and height as a compound variable (Dbh^2H) were the most suitable for estimating aboveground and total biomass, with 87–92% of explained variance. For the root components, wood density and crown diameter were additionally found to improve model performance for *R. racemosa* and *A. germinans*, respectively. Our study revealed that biomass in West African mangrove forests was more accurately predicted using the established equations than with the existing models.

Keywords: *Rhizophora racemosa Avicennia germinans* Allometry Biomass equations Mangroves Benin

Genetic and morphological diversity in populations of *Annona senegalensis Pers*. occurring in Western (Benin) and Southern (Mozambique) Africa

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Understanding morpho-genetic diversity and differentiation of species with relatively large distributions is crucial for the conservation and sustainable management of their genetic resources. The present study focused on *Annona senegalensis* Pers., an important multipurpose wild plant, distributed exclusively in natural ecosystems but facing several threats. The study assessed the genetic and morphological diversity, structure, and differentiation of the species in populations from Western (Benin) and Southern (Mozambique) Africa. The material was evaluated to ascertain the environmental (climatic) determinants of the variation within this species. Four sub-populations comprised of 154 individuals were phenotyped based on nineteen plant, fruit, and leaf morphological traits and further genotyped using ten polymorphic nuclear microsatellite (nSSR) markers. The results indicated strong differences in plant, fruit, and leaf morphological traits between Western and Southern populations. Furthermore, the studied populations were characterized by high genetic diversity, with an average genetic diversity index of 1.02. Western populations showed higher heterozygosity values (0.61–0.71) than Southern populations (0.41–0.49). Western and Southern populations were clearly differentiated into two different genetic groups, with further genetic subdivisions reflecting four sub-populations. Genetic variation between regions (populations) was higher (69.1%) than among (21.3%) and within (9.6%) sub-populations. Four distinct morphological clusters were obtained, which were strongly associated with the four genetic groups representing each sub-population. Climate, mainly precipitation and temperature indexes, explained the relatively higher variation found in morphological traits from Western (40.47%) in relation to Southern (27.98%) populations. Our study suggests that both environmental and genetic dynamics play an important role in the development of morphological variation in A. senegalensis.

Keywords: *Annona senegalensis*, Bioclimatic variables, Genetic diversity, Morphological diversity, Tropical plants, Environment

The relative role of soil, climate, and genotype in the variation of nutritional value of *Annona senegalensis* fruits and leaves

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Annona senegalensis Pers is a multipurpose tree species valued for food and medicinal uses in Africa. Although there have been attempts to document the proximate composition of fruits and leaves, little is known about the relative role of soil, climate, and genotype on the nutritional quality. The present study evaluated the variation of the proximate composition of fruits and leaves in populations from Benin and Mozambique. It further assessed the impact of soil, climate, and genotype on the proximate composition. Data were collected from four populations genetically different and analyzed using descriptive statistics, analysis of variance (ANOVA), principal component analysis, redundancy analysis (RDA), and variance partitioning. Results revealed significant variation in the proximate composition of fruits and leaves among the studied populations. Ashes and fibers in fruits, and lipids in leaves were 4.8-fold, 2.5- fold, and 1.25-fold higher respectively, in populations from Mozambique. Fruits moisture and lipids content were rather 1.4-fold and 1.10-fold higher in populations from Benin. Moisture and lipids were respectively 6-fold and 1.27-fold higher in fruits than in leaves, while ashes, fibers and proteins were approximately twice higher in the leaves than in the fruits. Genetic groups, climate and soils were found to influence this variation. All three factors explained 74.4% of the variation of nutritional value of fruits and leaves, 31.9% of which was exclusively due to genetic variation, 2.8% to the interaction of climate and soils, 24.1% to the interaction of soil and genetic variation, and 15.5% to the interaction of all three factors. Our study shows that genetic variation and soil properties better than climate, explain the variation of nutritional value of *A. senegalensis* fruits and leaves and further provides essential information that could be harnessed in the domestication and breeding program of the species for its edible parts.

Keywords: Proximate composition Variability Macronutrients *Annona senegalensis*

Co-management brings hope for effective biodiversity conservation and socio-economic development in Vwaza Marsh Wildlife Reserve in Malawi

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Frontiers in Conservation Science, 4, 1124142.
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Co-management has been widely promoted in protected area management on the premise that it may simultaneously enhance biodiversity conservation outcomes and improve livelihoods of the park-border communities. However, the success of this management approach remains a growing debate raising the question of its effectiveness. To contribute to this debate, we used local community perceptions and secondary ecological data to assess the extent to which co-management has effectively contributed to biodiversity conservation and socio-economic development outcomes in the Vwaza Marsh Wildlife Reserve. Face-to-face individual interviews using a semi-structured questionnaire were used to collect data on the perceptions of co-management from 160 purposively selected heads of households. A desk study was used to collect data on trends in animal populations, animal mortality, and prohibited activities including incidences of poaching for the past 30 years (pre-and post-introduction of co-management). Results showed that local communities have positive perceptions of the conservation work in the Vwaza Marsh Wildlife Reserve. Further, there was an improved people-park relationship and a recovery of animal populations in the reserve after the introduction of co-management. These findings point to the success of comanagement in the area. However, misunderstandings over revenue sharing were still a thorny issue, somehow creating mistrust between parties. We concluded that while it may still be early to achieve more demonstrable conservation outcomes, co-management appears to bring hope for effective biodiversity conservation and socio-economic development in the Vwaza Marsh Wildlife Reserve. Participatory evaluation of co-management involving key stakeholders is recommended in the Vwaza Marsh Wildlife Reserve based on the findings of this study and lessons learnt over the years.

Keywords: community perceptions, collaborative management, protected area management, community-based natural resources management, rural livelihood

Deep learning methods for biotic and abiotic stresses detection and classification in fruits and vegetables: State of the art and perspectives

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Deep Learning (DL), a type of Machine Learning, has gained significant interest in many fields, including agriculture. This paper aims to shed light on deep learning techniques used in agriculture for abiotic and biotic stress detection in fruits and vegetables, their benefits, and the challenges faced by users. Scientific papers were collected from Web of Science, Scopus, Google Scholar, Springer, and Directory of Open Access Journals (DOAJ) using combinations of specific keywords such as: Deep Learning' OR 'Artificial Intelligence' in combination with fruit disease', vegetable disease', 'fruit stress', OR 'vegetable stress' following PRISMA guidelines. From the initial 818 papers identified using the keywords, 132 were reviewed after excluding books, reviews, and the irrelevant. The recovered scientific papers were from 2003 to 2022; 93 % addressed biotic stress on fruits and vegetables. The most common biotic stresses on species are fungal diseases (grey spots, brown spots, black spots, downy mildew, powdery mildew, and anthracnose). Few studies were interested in abiotic stresses (nutrient deficiency, water stress, light intensity, and heavy metal contamination). Deep Learning and Convolutional Neural Networks were the most used keywords, with Google Net (18.28%), ResNet50 (16.67%), and VGG16 (16.67%) as the most used architectures. Fifty-two percent of the data used to compile these models come from the fields, followed by data obtained online. Precision problems due to unbalanced classes and the small size of some databases were also analyzed. We provided the research gaps and some perspectives from the reviewed papers. Further research works are required for a deep understanding of the use of machine learning techniques in fruit and vegetable studies: collection of large datasets according to different scenarios on fruit and vegetable diseases, evaluation of the effect of climatic variability on the fruit and vegetable yield using AI methods and more abiotic stress studies.

Keywords: Deep learning Prediction Fruits Vegetables Stress Agricultural yield

Midterm change in rainfall distribution in north and central Benin: implications for agricultural decision making

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Environment, Development and Sustainability, 1-26
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A better understanding of rainfall variability and trends is vital for agricultural production systems which are largely dependent on climate. This study aims to analyze and to quantify the significance of change on annual, seasonal, and daily rainfall in North and Central Benin, and to infer future challenges for crop production. Daily rainfall data for the 1970–2016 period measured at three weather stations (Savè, Malanville and Tanguiéta) were obtained from the Benin National Weather Agency. Descriptive statistics, standardized anomaly of rainfall (SAR) and rainfall intensity were used to analyze rainfall variability. For rainfall trends analysis, we tested for auto-correlation and used the Mann–Kendall and modified Mann–Kendall tests for non-auto-correlated and auto-correlated data, respectively. Trend magnitude was estimated using Sen's slope. Globally, a moderate-to-high seasonal rainfall and low variability of yearly rainfall were observed. The SAR indicated more than 50% of the years in the studies period experienced dry years. Between 1970 and 2016, a significant 20% increase was observed in the yearly rainfall in Tanguiéta, whereas no significant trends were observed in Malanville (10% increase) and Savè (0.6% decrease). The general rainfall increase observed during the post-monsoon season (October–November) in the three weather stations potentially increases food frequencies during the harvest period of some crops, which can reduce crop yields. Adaptation strategies are needed which can mitigate the effects of climate change on agriculture. These findings are essential to the climate risk management in agriculture and to target appropriate adaptive measures for resilience building in the sector.

Keywords: Climate change Rainfall Cropping seasons Risk management Agriculture National adaptation plan (NAP)

Uses, Cultural Importance, and Fire Threat to *Pseudocedrela kotschyi* (Meliaceae): Evidence for the Availability Hypothesis in Benin (West Africa)

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Economic Botany, 77, 305-323
DOI: https://doi.org/10.1007/s12231-023-09581-y

Pseudocedrela kotschyi is one of the most widely exploited species in Benin. Therefore, populations of the species are faced with the issue of human disturbance. This study investigated the ethnobotanical knowledge of the species to set sustainable management strategies. Individual face-to-face semi-structured interviews were conducted with 324 respondents in the three climatic zones of Benin according to two levels of abundance (low and high abundance) of the species per zone. Reported use values (RUV), importance score (IS), overall use values for each use category (UV), and overall cultural importance indices (CI) were calculated. Poisson family generalized linear models were used to identify the socio-environmental factors that determined the uses and the importance of the species. The results showed that climatic zone had a significant influence ($p < 0.001$) on the reported use values of *P. kotschyi*, whereas climatic zone ($p = 0.032$) and abundance status ($p = 0.025$) were the two factors that had a significant effect on the cultural importance of *P. kotschyi*. These findings support the availability hypothesis in ethnobotany. According to local knowledge, fire was the main threat to the species in natural habitats, and such local knowledge depended on ethnicity and education level. Overall, the results of this study can be used for the sustainable management of *P. kotschyi*

Keywords: Sustainability, abundance, use value, fire threat, cultural importance, *Pseudocedrela kotschyi*

Vulnerability of *Parkia biglobosa*, *Vitellaria paradoxa* and *Vitex doniana* to climate change: wild indigenous agroforestry species in Benin

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Modeling Earth Systems and Environment, 1-16
DOI: https://doi.org/10.1007/s40808-023-01856-6

Climate change is a major threat to biodiversity, with global greenhouse gas emissions exceeding the Paris Agreement, which has a significant impact on the distribution of species at risk of facing extinction. Thus, predicting climate change's influence on species distribution is crucial. In Sub-Saharan Africa, particularly in Benin, some useful plants such as *Parkia biglobosa*, *Vitex doniana*, and *Vitellaria paradoxa* contribute greatly to improving socio-economic standards. However, they are subjected to overexploitation and climate change, which potentially could lead to their extinction. To predict the habitat suitability of these native agroforestry species for their conservation and cultivation, we assessed the best-performing algorithm among Maximum Entropy, Random Forest, Support Vector Machine, Generalized Linear Models and Boosted Regression Tree. Data were collected from field occurrences and Global Biodiversity Information Facility and coupled with environment variables selected based on collinearity tests, contribution of variables, and Jackknife tests. We analyzed the main variables affecting their distribution under Representative Concentration Pathways (RCP) 4.5 and RCP 8.5 scenarios by the year 2055. Results showed that Random Forest (RF) was the most appropriate model for predicting the distribution of the three species, with an area under the curve (AUC)>0.90. Cation exchange capacity, isothermality, and potential evapotranspiration are the environmental factors that all three species depend on. Under current environmental conditions, *P. biglobosa, V. paradoxa*, and *V. doniana* covered 52.10%, 76.91%, and 70.22% of the suitable habitats throughout the study area (11,540 km^2). A probable expansion of the suitable habitats was noted, with up to 76.19% for *P. biglobosa* and 82.82% for *V. paradoxa*. Exceptionally, *V. doniana* will lose 7.36% of its suitable habitats under the pessimistic (RCP 8.5) scenarios by the year 2055. These findings represent a step forward in the process of conserving *P. biglobosa*, *V. paradoxa*, and *V. doniana* in appropriate habitats in the context of climate change.

Keywords: Ecological niche Climate change Algorithms IPCC Soil fertility Random Forest

Habitat range shift and prediction of the potential future distribution of *Ricinodendron heudelotii (Baill.) Heckel* in Benin (West Africa)

Hounsou-Dindin G., Idohou R., Agre P., Hounkpèvi A., Adomou A.C., Assogbadjo A.E.,Glèlè Kakaï R.

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DOI: https://doi.org/10.1016/j.heliyon.2023.e20199

Ricinodendron heudelotii (Baill.) Heckel is an important nutraceutical reservoir. Its Sustainable exploitation requires information on its potential distribution in the current context of rapid population growth and climate change threats. This study aimed to map the suitable areas for its domestication and conservation under current and future climate conditions in Benin. Occurrence data were recorded and combined with the environmental layers of two climatic scenarios (optimistic RCP 4.5 and pessimistic RCP 8.5) following the biodiversity modelling approach (biomod2). Currently, about four percent (5082 Km2) of the country's area mainly located in the sub-humid and the humid zones were potentially suitable for *R. heudelotii* distribution. Under future climatic conditions the potentially suitable areas were mainly in the sub-humid zone, but almost all the highly suitable areas located in the humid zone will become medium suitable areas by the years 2055 and 2085 horizons. This study shows that, whatever the future climatic scenarios, *R. heudelotii* will substantially maintain the size of its range across the country. These findings allow undertaking anticipated actions to better adapt to the potential effects of climate change and to better guide policies for the conservation and development of forest resources.

Keywords: biomod2 Climate change Habitat suitability modelling Spatial distribution Wild oil species

Insights from analyzing local ecological knowledge and stand structure for guiding conservation actions for the endangered tropical tree *Pterocarpus erinaceus. Poir*

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Trees, Forests and People, 14, 100447
DOI: https://doi.org/10.1016/j.tfp.2023.100447

Sustainable management and conservation of multipurpose tree species in their natural habitats is crucial, given their vulnerability to climate change and increasing human activities. This can be achieved by harnessing insights

from local ecological knowledge (LEK) and classical ecological approaches to support biodiversity conservation efforts. Using forest inventory data from 126 plots and information from a semi-structured survey of 234 households, we investigated LEK (perception on population trend, causes, and conservation attitudes toward the species) and population ecology (tree density, size class distribution, SCD, structural diversity, and stability) of the endangered rosewood *Pterocarpus erinaceus* Poir. along a climate gradient in Benin (Sudanian (SZ), Sudano-Guinean (SGZ) and Guinean (GZ)). The results indicated that local communities were aware of the decline of *P. erinaceus* populations, although variations were observed with respect to ethnicity and age. The protection of the species regeneration by the communities in the GZ (63 %) probably led to the high regeneration rate (90 %) of *P. erinaceus* in this zone. Tree density declined from the SZ to GZ (2 and 1.23 times lower in SGZ and GZ compared to SZ), but variation in the mean diameter at breast height showed the opposite pattern (1.98 and 1.90 times lower in SGZ and SZ than in GZ). The SCD in the SGZ exhibited a bell-shaped pattern, while the populations in the SZ and GZ showed an inverted J-shaped distribution. Pruning intensity was 6.60 to 35.25 times higher in the SZ than in the SGZ and GZ, respectively, where regeneration rates were low, reflecting the potential negative effects of pruning on regeneration. Furthermore, *P. erinaceus* demonstrated tolerance for mixed-species stands (mingling of 40 % to 75 %), indicating an opportunity to integrate it into agroforestry systems with other species. This research highlights the impacts of human activity and climate conditions on *P. erinaceus* populations and informs on potential management actions needed for the conservation of the species.

Keywords: Adaptation Structural diversity Diameter differentiation Local perception Pruning intensity Benin

Connaissances et perspectives de recherche sur Detarium senegalense, une espèce vulnérable en Afrique

Trekpo P., Houenon G.H.A., Hounsou-Dindin G., Natta A., Adomou A.C., Kokou K.

Revue Marocaine des Sciences Agronomiques et Vétérinaires, 11(3), 313-320

Detarium senegalense est un arbre fruitier sauvage largement utilisé en Afrique. L'espèce est majoritairement utilisée pour l'alimentation, la médecine traditionnelle et comme bois d'œuvre. Dans le but de synthétiser les connaissances existantes, d'identifier les lacunes dans ces connaissances sur *D. senegalense* afin de proposer des perspectives de recherches futures, des documents scientifiques ont été consultés dans des bases de recherches comme Web of science, Scopus, Oare, Dimensions et Google Scholar. Après différentes opérations de filtres, 32 articles ont été retenus comme éligibles. A ces documents obtenus en ligne, 8 autres documents scientifiques dont 5 thèses et 5 livres, jugés pertinents ont été consultés dans des bibliothèques, soit un total de 42 documents utilisés pour la réalisation de cette revue. Ces documents ont couvert la période de 1932 à 2021. Les résultats ont montré que les principales thématiques abordées sur l'espèce sont la phytochimie, les activités biologiques et l'ethnobotanique. La pulpe du fruit de l'espèce est riche en vitamine C et est utilisée dans la préparation de nombreux mets. Quant aux amandes, elles font l'objet d'un commerce international. Les tiges, feuilles, écorces et racines sont employées dans le traitement de plusieurs affections dont les maux de ventre, la dysenterie et la dermatose. Cette revue a confirmé la surexploitation des individus de *D. senegalense*. Dans ce contexte, des perspectives de recherches futures devraient s'orienter sur sa biologie de reproduction afin de promouvoir son utilisation durable.

Keywords : *D. senegalense,* taxonomie, écologie, ethnobotanique, menaces

Impacts of harvesting intensity on carbon allocation to species, size classes and pools in mangrove forests, and the relationships with stand structural attributes

Zanvo S.M.G., Salako K.V., Mensah S., Glèlè Kakaï R.

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Mangroves are vital ecosystems that help mitigate climate change and natural hazards, despite representing only 0.5% of the world's coastlines. Recent studies have provided empirical evidence of the ongoing over-exploitation of mangrove forests in West Africa. Understanding the impact of such harvesting on mangroves' carbon potential is essential to inform decision-making for management and carbon economy policies. This study investigated the impacts of harvesting intensity on (i) carbon allocation to species, size class, soil depth and pool (standing live trees, standing dead trees, litter and soil); and (ii) carbon stock in the different carbon pools, and its relationships with stand structural attributes, using the case study of Benin coastal line. Data were collected in 600 plots of 0.015 ha

across 20 mangrove sites in high and low-harvesting-intensity areas. Sixty litter quadrats were also established to sample litter, while 160 soil samples were collected for soil carbon content analysis. Regardless of the harvesting intensity, two mangrove species, *Rhizophora racemosa* and *Avicennia germinans*, contributed more than 98% of the tree carbon. Small (1–10 cm) and medium (10–20 cm) size classes dominated tree carbon in high and low harvesting sites, respectively. Soil carbon up to 1 m depth had the greatest share (55%-70%) of the total carbon stock, followed by standing live trees (26%-40%) and litter, and was not influenced by harvesting intensity. Harvesting intensity influenced the carbon stocks in standing live and dead trees, with greater values in low and high harvesting sites. The total carbon stock was ~ 1.46-fold higher in low harvesting sites (308.54 ± 32.74 MgC.ha− 1) than in high harvesting sites (211.40 ± 14.91 MgC.ha^{-1}). Mixed effect models showed that stand density and proportion of *R. racemosa* related positively with tree carbon stock, especially on low harvesting sites. Multiple factorial analyses revealed that carbon stocks in dead trees, litter and soil are high in low harvesting areas where stand densities are also high. However, in high harvesting sites, carbon stock in litter was positively related to relative density of *A. germinans*. This study expands our understanding of the carbon stock potential in a West African mangrove subject to different levels of disturbance and its contribution to mitigating greenhouse gas emissions. The implications for management were further discussed.

Keywords: *Avicennia germinans* Benin Disturbances *Rhizophora racemosa* Soil carbon Tree carbon

Quality report of infectious disease modeling techniques for point-referenced spatial data: A Systematic review

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Spatial data modeling can provide significant value to healthcare organizations by improving decision support, resource management and distribution, and clinical outcomes. The aim of this study was to (i) summarize the trends of the modeling techniques used to analyze point-referenced spatial data in epidemiology and (ii) examine if all information required when applying these modeling techniques were properly reported in the published papers. A literature search was limited to journal papers published from January 2010 to June 2022 using PubMed, Scopus, Crossref, and Google Scholar. From 528 articles identified with the defined keywords, 351 were retained for the review. The results revealed that the use of modeling techniques in spatial data for infectious diseases increases exponentially over time. The most common spatial method was Empirical Bayesian Kriging [EBK] (52% of the selected articles), followed by Spatial GLMMs (34%) and Spatial smoothing Kernel Estimation (13%).

Keywords: spatial models; disease mapping; smoothing methods; quality assessment; epidemiology

Empirical Performance of CART, C5.0 and Random Forest Classification Algorithmsfor Decision Trees

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DOI: http://dx.doi.org/10.16929/ajas/2023.1399.274

This study compares the performance of CART, C5.0 and Random Forest (RF) algorithms. 25 continuous predictors and factors were simulated using a population size of 10,000. Based on this data, sample data were generated varying the number of predictors, the proportion of categorical versus continuous predictors and the sample size. The performance of the tree algorithms increases with sample size and the number of variables, but for RF, it is highly greater than the one of CART and C5.0. Irrespective of the algorithms, the performance decreases when there are more categorical variables than continuous variables.

Keywords: accuracy; categorical variables; specificity; non-parametric modeling; simulation

Model selection criteria for survival data based on Kullback's divergence: A systematic and critical review

Dete H.C., Senou M., Kossi M., Glelèlè Kaka R.

Afrika Statistika, 18(1), 3379-3398
DOI: http://dx.doi.org/10.16929/as/2023.3379.310

We did a literature review to summarize the trends in the model selection criteria derived from Kullback's divergence in survival analysis. Furthermore, we conducted comprehensive discussions on these criteria to enhance the users' understanding. Therefore, 4628 original papers on model selection criteria in survival analysis are identified via keyword searching using Pubmed, Web of Science, and Scopus search engines. Subsequently, 304 studies were fully analyzed, excluding those that did not utilize criteria based on Kullback's divergence for model selection. The most reported model selection criteria were the AIC and the AICc. Surprisingly, none of the selected papers discussed of the KIC family model selection criteria.

Keywords: Survival analysis, model selection criteria, Kullback's divergence, performance.

Phylogenetic diversity and community wide-trait means offer different insights into mechanisms regulating aboveground carbon storage

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Science of the Total Environment, 907, 167905
DOI: https://doi.org/10.1016/j.scitotenv.2023.167905

Both attributes of functional traits and phylogenetic diversity influence ecosystem functions, but which of these factors is most important is still poorly understood in natural systems. Using data from West African forests and tree savannas, we analyse how (i) phylogenetic diversity complements attributes of functional traits in explaining aboveground carbon (AGC); (ii) phylogenetic diversity relates with attributes of functional traits along gradients of phylogenetic signal; and (iii) pathways between phylogenetic diversity and attributes of functional traits relate AGC to soil and climate. Phylogenetic diversity was measured as standardised effect size of Mean Pairwise Distance (sesMPD) and Mean Nearest Taxon Distance (sesMNTD). Functional dispersion (FDis) and community weighted mean (CWM) were calculated for four traits related to leaf economics spectrum and plant life-history. Functional traits-based models explained 11 % of AGC variability. With two out of the four traits being phylogenetically conserved, incorporating phylogenetic diversity in the models increased the explained variance in AGC by 15 %. The slope of phylogenetic diversity-trait relationship was more responsive to trait conservatism.

Keywords: Functional dispersion Maximum plant height Mean pairwise distance Phylogenetic signal Tree and shrub savannas West Africa

Residents' perception and impact of COVID-19 on ecotourism in West Africa: The case of Banco National Park in Cote ˆ d'Ivoire

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Heliyon, 9(11), e21832
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Ecotourism, as a means of fostering socio-economic level of local communities and contributing to the conservation of forest resources, is important for development in low-income countries. This work investigates the extent to which local people support the continuation of ecotourism during the COVID-19 pandemic and their attitudes towards resource conservation in Banco National Park in Cote ˆ d'Ivoire using social exchange theory (SET) as a foundation. A closed-ended questionnaire was used to conduct a survey with 150 informants selected among residents around the park. The data were analyzed using descriptive, correlational, and Partial Least Squares Structural Equation Modelling (PLS-SEM) approaches. The results showed that residents' perception of the impacts of ecotourism strongly affects their support for tourism development during the COVID19 pandemic ($\beta = 0.918$, $p < 0.05$). The socio-cultural ($\beta = 0.275$, $p < 0.05$) and environmental ($\beta = 0.309$, $p < 0.05$) benefits of ecotourism are the key determinants of the residents' perception and their support for ecotourism within the park during COVID-19

pandemic. The findings also revealed that economic benefits from ecotourism are linked to residents' perceptions of the qualities of the tourism place ($\beta = 0.363$, $p < 0.05$). Overall, local people around Banco Park recognize that ecotourism produces more benefits than detriments. The COVID-19 pandemic, a painful and unexpected event, has not blunted their support for the continuation of ecotourism. This study calls for the integration of local residents' opinions in the development of the ecotourism sector in Cote ˆ d'Ivoire. It is a first step in determining residents' attitudes towards ecotourism in West Africa in a post-COVID context, and the results constitute a starting point for future studies.

Keywords: Residents' attitudes Support for tourism SARS-CoV-2 Sustainable tourism development Perceived environmental benefit Socio-economic benefit Ivory Coasty

The dynamics of vegetation diversity and biomass under traditional grazing in Ethiopia's Somali rangeland

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Plant-Environment Interactions, 4(6), 342-352
DOI: https://doi.org/10.1002/pei3.10127

Traditional grazing management practices are central to rangeland productivity and biodiversity. However, the degradation of rangelands and loss of ecosystem services have raised concerns about the future of pastoralism as a form of land use. It is imperative to understand how these practices influence vegetation attributes, e.g., herbaceous species diversity and composition, growth forms (grass, forbs), life form (annuals, perennials), tree metrics (density, canopy cover, and biomass). This study evaluates vegetation shifts under three grazing management practices-enclosures, open grazing, and browsing lands-in the Somali pastoral ecosystem of Ethiopia. Enclosures exhibited the highest diversity in herbaceous species, with open grazing lands favoring forbs and annuals. Distinct compositional shifts in herbaceous species were observed across regimes, especially in grass and annuals. Enclosures had three times higher herbage biomass of open grazing and double that of browsing management practice. Conversely, browsing management practices presented optimal wood biomass, density, and canopy cover. The results highlight that a transition to combined enclosure and browsing practices can elevate plant production and diversity, benefiting the Somali rangeland economy. Consequently, dryland restoration should incorporate indigenous knowledge to ensure future rangeland sustainability and biodiversity preservation.

Keywords: Ethiopia pastoralism, herbaceous species diversity, rangeland productivity, vegetation attributes

Simulation of the Impacts of Sea-Level Rise on Coastal Ecosystems in Benin Using a Combined Approach of Machine Learning and the Sea Level Affecting Marshes Model

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Sustainability, 15(22), 16001
DOI: https://doi.org/10.3390/su1522160012023

Sea-level rise in Benin coastal zones leads to risks of erosion and flooding, which have significant consequences on the socio-economic life of the local population. In this paper, erosion, flood risk, and greenhouse gas sequestration resulting from sea-level rise in the coastal zone of the Benin coast were assessed with the Sea Level Affecting Marshes Model (SLAMM) using ArcGISPro 3.1 tools. The input features used were the Digital Elevation Map (DEM), the National Wetland Inventory (NWI) categories, and the slope of each cell. National Wetland Inventory (NWI) categories were then created using Support Vector Machines (SVMs), a supervised machine learning technique. The research simulated the effects of a 1.468 m sea-level rise in the study area from 2021 to 2090, considering wetland types, marsh accretion, wave erosion, and surface elevation changes. The largest land cover increases were observed in Estuarine Open Water and Open Ocean, expanding by approximately 106.2 hectares across different sea-level rise scenarios (RCP 8.5_Upper Limit). These gains were counterbalanced by losses of approximately 106.2 hectares in Inland Open Water, Ocean Beaches, Mangroves, Regularly Flooded Marsh, Swamp, Undeveloped, and Developed Dryland. Notably, Estuarine Open Water (97.7 hectares) and Open Ocean (8.5 hectares) experienced the most significant expansion, indicating submergence and saltwater intrusion by 2090 due to sea-level rise. The largest reductions occurred in less tidally influenced categories like Inland Open Water (−81.4 hectares), Ocean Beach (−7.9 hectares), Swamp (−5.1 hectares), Regularly Flooded Marsh (−4.6 hectares), and Undeveloped Dryland (−2.9 hectares). As the sea-level rises by 1.468 m, these categories are expected to be notably diminished, with Estuarine

Open Water and Open Ocean becoming dominant. Erosion and flooding in the coastal zone are projected to have severe adverse impacts, including a gradual decline in greenhouse gas sequestration capacity. The outputs of this research will aid coastal management organizations in evaluating the consequences of sea-level rise and identifying areas with high mitigation requirements.

Keywords: sea -level rise; machine learning; SLAMM model; coastal ecosystems; Benin

Impacts des tabous et des cérémonies rituelles sur la structure des peuplements de *Triplochiton scleroxylon* K. Schum., un arbre sacré au Bénin

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Bois et Forêts des Tropiques, 357, 57-70
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Triplochiton scleroxylon (samba ou ayous ou abachi ou obeche ou wawa) est une espèce culturelle clé du culte Orisha Oro au Bénin, dont les populations naturelles sont en déclin. Les informations sur les schémas spatiaux des arbres de cette espèce sont quasiment non documentées, ce qui limite la mise en œuvre d'une restauration écologique de ses populations. Cette étude vise à évaluer les modèles démographiques et spatiaux actuels de *T. scleroxylon* en fonction des tabous relatifs à l'espèce et de la fréquence des cérémonies rituelles du culte au Bénin. Des inventaires et une cartographie des pieds de l'espèce dans 12 placeaux de 100 m × 100 m ont été réalisés. L'étude a comparé la densité et la hauteur totale des arbres, leur distribution selon les classes de diamètre et les schémas spatiaux suivant les formations soumises à différentes proportions de tabous et fréquences de cérémonies rituelles. Les résultats ont montré, d'une part, que le nombre des tabous a un effet positif et, d'autre part, que la fréquence des cérémonies rituelles du culte a un effet négatif sur les peuplements à *T. scleroxylon*. Les densités de tiges juvéniles et adultes étaient respectivement trois et deux fois supérieures dans les forêts soumises à un plus grand nombre de tabous et un faible nombre de cérémonies rituelles. La distribution des arbres en classes de diamètre présente des tendances similaires. Cependant, l'analyse de la structure spatiale des arbres indique globalement une distribution aléatoire et une indépendance des juvéniles par rapport aux adultes. Compte tenu des rituels liés à *T. scleroxylon* en raison de sa position d'espèce centrale lors des cérémonies du culte Orisha Oro, sa sacralisation ne peut pas garantir sa conservation. L'utilisation durable et la conservation de *T. scleroxylon* nécessitent une sensibilisation des dignitaires des forêts sacrées à la réduction des fréquences des cérémonies rituelles, à la préservation stricte des grands semenciers, et à l'enrichissement des forêts sacrées et la promotion des plantations de l'espèce.

Keywords : samba, interdits, cultes, structure démographique, répartition spatiale, Bénin, Afrique de l'Ouest

Challenges and opportunities existing in the floriculture industry in Africa: knowledge and future research prospects

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Journal of Biological Research & Biotechnology, 21(3), 2167-2177
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Floriculture is a growing sector and represents an asset to the economy of most developing countries in Africa. This paper aims to access the existing knowledge gaps and how such gaps might be filled to develop the floriculture industry sustainably in Africa. Scientific information on the floriculture industry was searched on three online databases (Science Direct, Google Scholar African Journals Online and PubMed) to gather much reliable data on the last 30 years in Africa. Thus, 23 scientific publications distributed in eight African countries were considered and examined. East African countries are the most interested in the floriculture industry, with Kenya and Ethiopia as the leaders. There are about a hundred ornamental plant in Africa and they are dominated by exotic species that sold (50%) in northern countries. The cut flowers and foliage are mainly used to brighten up party days, insightful human well-being and the perfumery industry, as well as landscape plants, for hedging, game cover, slope stabilization, food, and aromatherapy. The most important challenges to tackle in floricultural production are related to climate change, pests, and pathogens attacks. Irrigated floricultural production, development, and culture of resistant and adaptative varieties, and creation of home markets are recommended to ensure sustainable improvement of environmental quality, food security, and socio-economic aggregate for communities.

Keywords: Ba Africa, Biodiversity, Cut flowers and foliage, Horticulture, Landscape quality, Ornamental plant

Analytical Insights of the Effects of Non-Pharmaceutical Interventions on SARSCoV-2 Dynamic with Application to West African Data

Traore K., Houenou D.F., Glèlè Kakaï R.

Contemporary Mathematics, 4(4), 1310-1330
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The COVID-19 pandemic was caused by the rapid spread of a new coronavirus (SARS-CoV-2) worldwide. COVID-19 pandemic mitigation measures caused significant social and economic disruption, especially in regions with weak economic and fragile healthcare systems like West Africa. Therefore, accurate knowledge of the impact of these measures on its dynamics is important in decision-making. In this study, we formulated and used a deterministic compartmental model, considering two sub-classes of susceptible individuals (S1 and S2), where S1 is the population living around the epicenter of the epidemic and S2 is the population living far from the epicenter of the epidemic. The aim was to (i) theoretically assess the impact of measures reducing the transmission rate of the disease (ψ) on the epidemic dynamics and (ii) analyze the impact of measures reducing the probability of contact between infected and susceptible individuals (detection and isolation rates, θap, θs) on the epidemic dynamics. We determined the expressions of the basic and control reproduction numbers and studied the sensitivity and elasticity of the control reproduction number with respect to ψ, θap, θs, and heterogeneity factor, k (S_1/S_2). Application to the COVID-19 first-wave data from West Africa revealed that the basic reproduction number was 1.85. Moreover, the results indicated that a 50% reduction in the transmission rate of COVID-19 or the detection and isolation of 10% of infected individuals per day should help to reach the peak of the epidemic. Furthermore, a 100% increase in the heterogeneity factor induces a 16% increase in the control reproduction number when θap = 0.15 and a 14% increase in the control reproduction number when θap = 0.6. These conclusions could help design control measures to curtail future epidemics.

Keywords: heterogeneous population, reproduction number, sensitivity and elasticity, transmission rate, type of control measures, mechanistic model

Tree size diversity is the major driver of aboveground carbon storage in dryland agroforestry parklands

Noulèkoun F., Mensah S., Kim H., Jo H., Gouwakinnou G.N., Houéhanou T.D., Mensah M., Naab J., Son Y., Khamzina A.

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Despite the importance of agroforestry parkland systems for ecosystem and livelihood benefits, evidence on determinants of carbon storage in parklands remains scarce. Here, we assessed the direct and indirect influence of human management (selective harvesting of trees), abiotic factors (climate, topography, and soil) and multiple attributes of species diversity (taxonomic, functional, and structural) on aboveground carbon (AGC) stocks in 51 parklands in drylands of Benin. We used linear mixed-effects regressions and structural equation modeling to test the relative effects of these predictors on AGC stocks. We found that structural diversity (tree size diversity, HDBH) had the strongest (effect size β= 0.59, R^2 = 54%) relationship with AGC stocks, followed by community weighted mean of maximum height (CWMMAXH). Taxonomic diversity had no significant direct relationship with AGC stocks but influenced the latter indirectly through its negative effect on CWMMAXH, reflecting the impact of species selection by farmers. Elevation and soil total organic carbon content positively influenced AGC stocks both directly and indirectly via HDBH. No significant association was found between AGC stocks and tree harvesting factor. Our results suggest the mass ratio, niche complementarity and environmental favorability as underlying mechanisms of AGC storage in the parklands. Our findings also highlight the potential role of human-driven filtering of local species pool in regulating the effect of biodiversity on AGC storage in the parklands. We conclude that the promotion of AGC stocks in parklands is dependent on protecting tree regeneration in addition to enhancing tree size diversity and managing tall-stature trees.

Both the selection and complementarity effects underpin the effect of structural diversity on aboveground biomass in tropical forests

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Global Ecology and Biogeography, 33(2), 325-340
DOI: https://doi.org/10.1111/geb.13800

Despite mounting empirical evidence regarding the positive effects of forest structural diversity (STRDIV) on forest functioning, the underlying biotic mechanisms and controlling abiotic factors remain poorly understood. This study provides the first assessment of the interactive effects of STRDIV and diversity in species and functional traits on aboveground biomass (AGB) in natural forests in West and East Africa. Using data from 276 plots and 7993 trees of 207 species distributed across various types of natural forests and major climatic zones of Africa, linear mixed-effects and structural equation models, we have evaluated how alternative causal relationships between STRDIV and taxonomic and functional diversity attributes influence AGB, while accounting for the effects of environmental covariates. We also assessed the consistency of these relationships across floristically and environmentally homogenous forest types. We found that the positive effects of STRDIV on AGB were underpinned by both the community-weighted mean (CWM) of trait values (selection effects) and species richness (niche complementarity), but the relative importance of these effects varied depending on forest types. Across the forest types, STRDIV primarily mediated the effects of CWM of traits and species richness on AGB. We also found that STRDIV–AGB relationships were constrained by resource (water and nutrient) availability. Our findings provide novel insights into the role of functional traits as key determinants of the effects of STRDIV on AGB in tropical forests. We suggest that forest management and climate change mitigation strategies aimed at conserving biodiversity, and fostering biomass storage through increased STRDIV should focus on maintaining high levels of functionally dominant species while also increasing tree species diversity.

Assessing the potential impact of climate change on *Kobus megaceros* in South Sudan: a combination of geostatistical and species distribution modelling

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Modeling Earth Systems and Environment, 1-12
DOI: https://doi.org/10.1007/s40808-023-01889-x

Kobus megaceros is a wetland antelope listed as endangered by United Nations Educational, Scientific and Cultural Organization (UNESCO) in its natural habitat in South Sudan. The population of the species in South Sudan's wetlands remains unknown. Climate change is expected to have a significant impact on the species population in a variety of ways. This paper aims to estimate the current population density and investigate the impact of climate change on *K. megaceros* by the end of the century. Bayesian Maximum Entropy (BME) and species distribution modelling (SDM) were used to estimate spatial density and predict habitat suitability for *Kobus megaceros* in RCP4.5 and RCP8.5 pathways. The observed occurrences and abundances of *Kobus megacero* were downloaded from the global biodiversity information facility (GBIF) website. The Africlim online database was used to gather environmental predictors for current and future scenarios. We implemented SDM in R biomod2 package with Maxent algorithm to determine the geographical extent of habitat suitability for RCP4.5 and RCP8.5. The area under the ROC curve (AUC) and true skill statistics (TSS) were used to evaluate the model. The findings revealed that the current population density of Nile lechwe is too small; hence, this could accelerate the extinction of Nile lechwe. Although 4.97% of the country is currently highly suitable, future scenarios show that about 79–83% of the current suitable habitat will be lost due to climate change in the mid-2055s and mid-2085s. This implies that a proactive conservation strategy should be implemented to reduce the species' chances of extinction.

Keywords : SDM, Geostatistics, BME, *Kobus megaceros*, Climate change, Habitat suitability

Caractéristiques structurales et dendrométriques des peuplements ligneux à *Detarium senegalense* J. F. Gmel dans le Dahomey Gap en Afrique de l'Ouest

Trekpo P., Hounsou-Dindin G., Issiako D., Adomou A.C., Kokou K.

Cette étude vise à évaluer les caractéristiques structurales des peuplements ligneux à *D. senegalense* suivant le type d'habitats est nécessaire afin de garantir une exploitation durable de l'espèce. Un total de 103 placeaux a été installé dans quatre zones phytogéographiques du Dahomey Gap. Le dbh, le type de régénération et la hauteur totale des arbres de *D. senegalense* collectés ont permis de calculer les paramètres dendrométriques. Les structures en diamètre ont été évaluées suivant la distribution théorique de Weibull. Dans les peuplements ligneux à *D. senegalense*, les valeurs moyennes de densité, surface terrière, dbh et densité de régénération sont respectivement 168,00 ± 45,25 tiges/ha ; 17,16 ± 8,55 m2 /ha, 36,51 ± 13,69 cm et 183,00 ± 24,04 tiges/ha. Quant aux populations de *D. senegalense*, les valeurs moyennes obtenues ces mêmes paramètres étaient de 14,00 ± 5,66 tiges/ha pour la densité des arbres, 4,42 ± 3,54 m2 /ha pour la surface terrière ; 70,10 ± 28,99 cm pour le dbh et 85,00 ± 120,21 tiges/ha pour la densité de régénération. Quant à la hauteur moyenne des arbres, la valeur obtenue était de 21,13 ± 7,67 m. Les groupements végétaux le long des cours d'eau sont les habitats plus favorables au développement des pieds de *D. senegalense* mais défavorables quant à la régénération naturelle de l'espèce du fait de la position occupé par les adultes engendrant ainsi le transport des graines sur des sites ne répondant pas à leur écologie. Les aires protégées sont également des sites de conservation par excellence de l'espèce. Les résultats de la présente étude ont révélé la nécessité d'envisager des programmes pour la domestication de *D. senegalense*. Par ailleurs, l'étude de la variabilité morphologique /phénotypique et des phases phénologiques permettra de mieux appréhender les modalités devant améliorer les conditions de régénération naturelle de *D. senegalense* et la restauration de ses habitats

Keywords : forêt, écosystème, groupement végétal, habitat, structure diamétrique, Dahomey Gap

Impact of mentoring on the likelihood of getting jobs in the agricultural sector in Benin

Kaki R.S., Houessou D.M., Gbedomon R.C., Thoto F.S., Gandji K., Aoudji A., Biaou G.

Development in Practice, 1-16
DOI: https://doi.org/10.1080/09614524.2023.2240039

This study evaluates the impact of mentoring programs on the likelihood of getting a job in the agricultural sector after a one-year experiment conducted in Benin. The program provides graduates in agriculture-related fields with capacity building (digital skills, job search skills, and interpersonal skills) – as well as the support of a professional who is either a junior (junior model) or a senior (senior model) – as they seek jobs. The evaluation framework followed a mixed-methods design that incorporated survey data and qualitative data. The findings from the randomised controlled trial (RCT) showed a positive impact of the senior mentoring model, which increased the likelihood of getting a job in the agricultural sector by 16.4 per cent. In addition, the senior mentoring model had more impact on the likelihood of getting a job for both genders with an increase of 18.7 per cent for men and 11.9 per cent for women. Furthermore, mentees valued receiving practical career-related assistance, a realistic perspective on the workplace, and psychological and emotional support. The study suggests the need for a comprehensive policy package by policymakers and the institutionalisation of a formal mentoring program by youth-serving organisations based on the senior model.

Keywords: Mentoring, agriculture graduates, job, impact evaluation, gender, randomised controlled trial

Genetic diversity and population structure of a threatened tree species *Afzelia africana* Sm. ex Pers. among climatic zones for conservation challenges in Benin (West Africa)

Houehanou T.D., Prinz K., Koua D., Hellwig F., Ebou A., Gouwakinnou G.N., Assogbadjo A.E., Glèlè Kakaï R., Zézé A.

Genetic Resources and Crop Evolution, 70:1617–1632
DOI: https://doi.org/10.1007/s10722-022-01523-2

Afzelia africana Sm. ex Pers. is an African endangered tree species whose natural populations are declining severely because of human pressure through logging, fodder, and fuel harvesting. Despite the importance of molecular

ecology in these decades, no information regarding population genetics is available to motivate the conservation of this tree species in Benin. This study was then carried out to assess the genetic diversity and population structure of *A. afrcana* from different zones by SSR markers analysis to infer conservation implications. Two hundred sixty-four split into twenty-six populations were sampled in the three climatic zones and genotyped at 11 SSR loci measuring genetic diversity and population structure analysis. High levels of genetic diversity were found over the three zones. Mean values of observed/expected heterozygosities ranged from 0.81 to 0.88 and from 0.75 to 0.77, respectively. The pattern of population structure revealed by SSR loci indicated three gene pools in North-West, North-East, and South Benin. The population of the Sudano-Guinean zone exchanges gene with the other zones. We observed a weak but statistically significant genetic differentiation among geographical zones regarding the values of Fst (Value = 0.028; p = 0.001). Significant isolation by distance was obtained with the Mantel test. The observed pattern of population and genetic diversity by SSR loci offers useful insights to guide sustainable management and conservation decision of *A. africana* populations in different climatic zones of Benin.

Keywords: Conservation genetics, *Afzelia africana*, SSR, Sustainable management, Benin

Continuous assessment of cowpea [*Vigna unguiculata* L. Walp.] nutritional status using diagnosis and recommendation integrated system approach

Anago F.N., Agbangba E.C., Dagbenonbakin G.D., Amadji L.G.

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Cowpea is one of the widely cultivated and consumed grain legumes in Africa, but its production is hampered by soil fertility degradation on farms. Here, we assessed the spatial nutritional diagnosis of cowpea and the variability of their productivity using the diagnosis and recommendation integrated system (DRIS) and geostatistics tool. We achieved a sampling of 200 geo-referred points in cowpea farms in four communes of Benin. In addition, we determined grain yield and the content of N, P, K, Ca, Mg, and Zn in the leaves. From DRIS, the order of nutrient deficiency was as follows: P > K > Ca > Zn > N > Mg; P > K > Ca > N > Zn > Mg; N > Mg > Zn > K > P > Ca; P > Ca > K > N > Mg > Zn, at Dassa-Zoume, Glazoue, Ketou, and Ouesse, respectively. Sampling points were close enough to detect the spatial variability of the DRIS Index, mean of nutrient balance index (NBIm), and cowpea productivity (spatial dependence index > 50%). The combined analysis of the cowpea relative yield and NBIm maps showed that the NBIm map effectively indicated the spatial distribution of cowpea productivity. The spatial variability of the DRIS index has provided an accurate guide to where adjustments to fertilization rates are needed.

Magnesium and zinc fertilisation improves rice yield and yield component responses to nitrogen, phosphorus, and potassium

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The aim of this study was to assess the effects of magnesium (Mg) and zinc (Zn) on the response of rice to nitrogen (N), phosphorus (P), and potassium (K) application. Two sets of field experiments were carried out in Benin. A Box Behnken Design with eight replications per year with treatments of N, P, potassium (K), Mg, and Zn was used for the first experiment, while a randomised complete block design with five treatments varying in Mg and Zn was used for the second experiment. Co-application of major nutrients with Mg and/or Zn significantly increased rice yield and nutrient use efficiencies. Co-application of N and Mg increased grain yield, filled grain rate, and 1 000 grains weight by 53.5, 7.10, and 7.34%, respectively. Likewise, the co-application of N with Zn increased rice yield, panicles per plant, and spikelets per panicle by 35.69, 14.78, and 6.06%, respectively. When P was co-applied with Zn, grain yield, spikelets per panicle, and the 1 000 grains weight increased by 27.21, 5.71, and 6.20%, respectively. The co-application of K with Mg led to an increase of grain yield and filling of grain by 24.28, and 5.71%, respectively. This study revealed the positive effects of Mg and Zn on rice yield response to the application of N, P, and K.

Keywords: agronomic efficiency, harvest index, micronutrients, secondary nutrients, rice fertilisation

Le cèdre des zones sèches (*Pseudocedrela kotschyi*) : état des connaissances et perspectives sur sa biologie de conservation (revue systématique)

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Le Cèdre des zones sèches (*Pseudocedrela kotschyi* (Schweinf.) Harms), originaire de l'Afrique de Ouest et de l'Est, est très important pour les communautés locales en raison de ses multiples utilisations, notamment alimentaires, médicinales, industrielles et technologiques. Toutefois, les connaissances relatives à la biologie de la conservation et la domestication de l'espèce sont très limitées. L'objectif de cette revue systématique est d'exploiter la littérature existante pour évaluer de manière critique les lacunes de connaissances sur la biologie de conservation de *P. kotschyi* et en déduire les opportunités de recherches sur l'espèce. A partir des moteurs de recherche scientifique (Google scholar) et les bases de données (Dimension, Scopus, PubMed, AJOL), les publications relatives aux utilisations, variations des paramètres structuraux et morphologiques, effets des changements climatiques et menaces de l'espèce ont été soumises à une sélection rigoureuse et une lecture critique. L'analyse critique de 224 publications scientifiques retenues, a montré que la littérature existante n'a pas abordé certains aspects cruciaux de la biologie de la conservation et la domestication de l'espèce. Plus précisément, il s'agit des thématiques relatives à l'influence des facteurs biotiques et abiotiques sur la distribution spatiale, la structure, la morphologie, la diversité génétique, les effets des changements climatiques sur les habitats favorables de l'espèce, ainsi que les facteurs influençant l'utilisation de l'espèce. Ces aspects constituent des lacunes de connaissances à combler. Cette revue de littérature confirme la gamme variée de propriétés phytochimiques, l'importance socioéconomique, la forte valeur d'usage de *P. kotschyi* pour les communautés locales et les menaces qui pèsent sur la ressource. Cependant, il est impératif de mener des recherches approfondies sur les facteurs expliquant son utilisation, sa distribution spatiale, sa morphologie, sa structure, sa diversité génétique, ainsi que sur l'impact des facteurs de menace, notamment les changements climatiques.

Keywords: *Pseudocedrela kotschyi*, ethnobotanique, distribution géographique, valeur culturelle, conservation.