Indian Journal of Advanced Botany (IJAB)
ISSN: 2582-9475 (Online), Volume-6 Issue-1, April 2026

# Update on the Diversity of Gallery Forests in the Sub-Sudanese Zone of Côte D'ivoire

**KOUADIO Yao Jean-Clovis, POUNDA Nomel Gnagne Jules Richard, MEVANLY Ouattara**

***Abstract*: *Various forms of anthropogenic pressure have significantly altered the structure and floristic composition of gallery forests, leading to a departure from their previously described floristic profile. In this context, the present study aims to update knowledge on the floristic composition of gallery forests in the sub-Sudanese region of Côte d'Ivoire. The methodology combined surface surveys and itinerant inventories. For each inventoried species, the family, genus, morphological type, and phytogeographic distribution were determined according to the APG IV classification. Species distribution across these characteristics was analyzed using bar charts and pie charts. Endemism was assessed by identifying species endemic to the West African forest block, with particular attention to those restricted to Côte d'Ivoire. The resulting floristic list was compared with the UICN Red List and the reference list in. The results show that the gallery forest flora comprises 153 species distributed among 122 genera and 51 families. The most represented families are Fabaceae, Moraceae, Rubiaceae, Euphorbiaceae, and Sapindaceae. A diachronic comparison between 1971 and 2025 highlights the persistence of a resilient floristic core dominated by Fabaceae, Rubiaceae, Moraceae, and Annonaceae. In contrast, formerly abundant families such as Euphorbiaceae, Sterculiaceae, and Meliaceae exhibit a marked decline, while Apocynaceae, Sapindaceae, and Combretaceae emerge as increasingly important families. Species from the Guineo-Congolese region and the transition zone are the most numerous. Structurally, shrubs predominate, followed by trees and lianas. The characteristic species currently observed include Berlinia grandiflora, Carapa procera, Cola gigantea, Cola laurifolia, Dialium guineense, Lecaniodiscus cupanioides, Ochna membranacea, Olax subscorpioidea, Synsepalum brevipes, and Phoenix reclinata. Overall, floristic diversity has declined since the 1971 inventories, with several hygrophilous species disappearing and being replaced by disturbance-tolerant taxa. Nevertheless, these gallery forests remain important refuges for threatened and endemic species, some of which are classified as rare or vulnerable by the IUCN and Aké-Assi.*

***Keywords*: *Gallery Forests, Flora, Sub-Sudanese Region.***

**Manuscript received on 03 February 2026 | First Revised Manuscript received on 13 February 2026 | Second Revised Manuscript received on 26 March 2026 | Manuscript Accepted on 15 April 2026 | Manuscript published on 30 April 2026.**

*Correspondence Author(s)

**KOUADIO Yao Jean-Clovis***, Assistant Professor, Laboratory of Natural Environments and Biodiversity Conservation, UFR Biosciences, Félix Houphouët-Boigny University, Abidjan, Côte d'Ivoire. Email ID: kouadio.clovis1@ufhb.edu.ci, ORCID ID: 0009-0000-8172-2133.

**POUNDA Nomel Gnagne Jules Richard**, Lecturer and Researcher, Plant Biology Laboratory, Department of Science and Technology, Higher Normal School, Abidjan, Côte d'Ivoire. Email ID: richard.nomel@yahoo.fr, ORCID ID: 0009-0000-2086-8673

**MEVANLY Ouattara**, Assistant Professor, Laboratory of Natural Environments and Biodiversity Conservation, UFR Biosciences, Félix Houphouët-Boigny University, Abidjan, Côte d'Ivoire. Email ID: mevouatt777@gmail.com



***Nomenclature:***
CNF: National Centre for Floristics
IUCN: International Union for Conservation of Nature
APG: Angiosperm Phylogeny Group
SZ: Sudano-Zambesian
GC: Guineo-Congolese

## I. INTRODUCTION

Gallery forests are dense, linear plant formations that line waterways, forming ecological corridors within savanna landscapes. They play a major ecological role. They regulate the local microclimate, protect soils from erosion, maintain cool areas, and contribute to plant biodiversity by providing refuge for many plant and animal species. As such, gallery forests provide numerous ecosystem services, including provisioning, regulating, and cultural services [6]. Examples include flood control, groundwater recharge, sediment and nutrient retention and export, water purification, biological diversity reservoirs, cultural values, recreation and tourism sites, climate change mitigation and adaptation [3].

Despite their importance, recent data on their floristic composition is lacking in the literature in Côte d'Ivoire. Indeed, existing studies date back several decades and no longer accurately reflect the current ecological reality, given ecological and anthropogenic dynamics. Furthermore, existing studies in the sub-Sudanese region focus mainly on savanna and forest formations as a whole, without any particular distinction for gallery forests [9]. This dilutes specific knowledge of the floristic communities in this region's gallery forests.

In recent years, increasing anthropogenic pressure, particularly from agriculture, grazing, logging, and bush fires, has led to significant degradation of these ecosystems [4]. These disturbances are likely to have profoundly altered the structure and composition of the plant communities previously described, compromising the representativeness of the old floristic data.

Given this observation, the question arises as to the current state of vegetation in the gallery forests of the sub-Sudanese region of Côte d'Ivoire. What is the current floristic composition of the gallery forests in the sub-Sudanese zone of Côte d'Ivoire, and to what extent does this composition differ from previous descriptions, due to degradation and changes in land use?

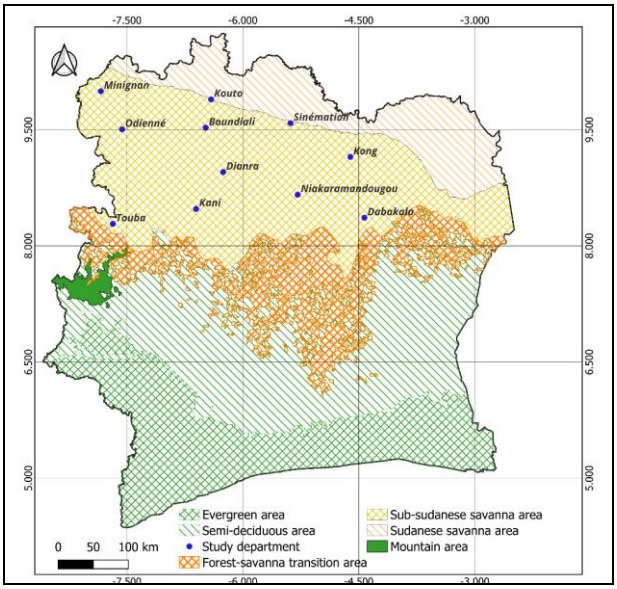
This study, carried out in the departments of Dabakala, Kong, Niakaramadougou, Sinematiali, Kani, Kouto, Touba, Minignan, Boundiali, Dianra, and Odienné as data-collection areas, aims to update floristic knowledge of these formations by providing a recent overview of their composition and specific diversity. Its overall objective is to update knowledge on the floristic

composition of gallery forests in the sub-Sudanese region of Côte d'Ivoire. More specifically, it aims to (1) identify woody and non-woody species present in the gallery forests of the sub-Sudanese zone and (2) compare the current floristic composition with the lists and descriptions found in older works.

## II. METHODOLOGY

### A. Study Area

Data collection took place in the departments of Dabakala, Kong, Niakaramadougou, Sinematiali, Kani, Kouto, Touba, Minignan, Boundiali, Dianra, and Odienné (Fig.1). These departments are part of the sub-Sudanese zone of Côte d'Ivoire, which corresponds to the northern part of the country, in transition between the Sudanese zone to the north and the Guinean zone to the south. It is characterized by wooded savanna vegetation interspersed with gallery forests along watercourses. It serves as an ecological transition between the humid Guinean domain, rich in dense semi-deciduous forests, and the dry Sudanese domain, dominated by grassy savannas and wooded steppes. This intermediate position gives it a mixed flora, with the coexistence of Guinean (forest) and Sudanese (savanna) species.




**[Fig.1: Geographical Location of Data Collection Sites]**

### B. Data Collection Method

The inventory methodology was based on surface surveys (or quadrats) and transect surveys. These two types of surveys complement each other. In the quadrats, all species encountered were identified, recorded, and counted. Transect surveys were conducted in all traversed areas, focusing solely on species not observed during surface surveys. Species identified during this second inventory were recorded, and samples were collected to enrich the overall floristic list. Species not identified in the field were collected, and a herbarium was created to facilitate their identification at the herbarium of the National Centre for Floristics (CNF) at Félix Houphouët-Boigny University.

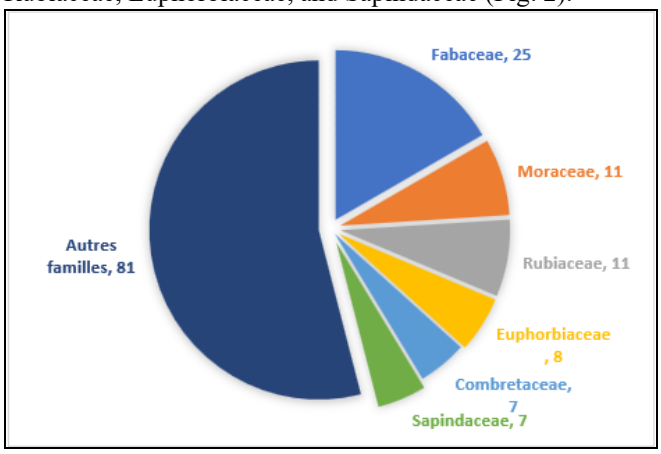
### C. Data Analysis Method

All floristic data were entered into Excel. For each species inventoried, the family, genus, biological and morphological type, and phytogeographic distribution were associated. Species identification was based on phylogenetic classification (APG IV). About phytogeographic distribution, species that occur naturally in the Guineo-Congolese (GC) phytogeographic region or in the Sudano-Zambesian (SZ) phytogeographic region, or in both of these phytogeographic regions (GC-SZ) were identified. Introduced exotic species (i) were also identified. Next, the distribution of species across these characteristics was analysed using bar and pie charts. For endemism, a distinction was made between species endemic to West African forest blocks (GCW), among which GCi designates those specific to the Ivorian territory. Finally, the resulting floristic list was compared with the Red List of [8] and the Aké-Assi list to identify threatened species.

## III. RESULTS

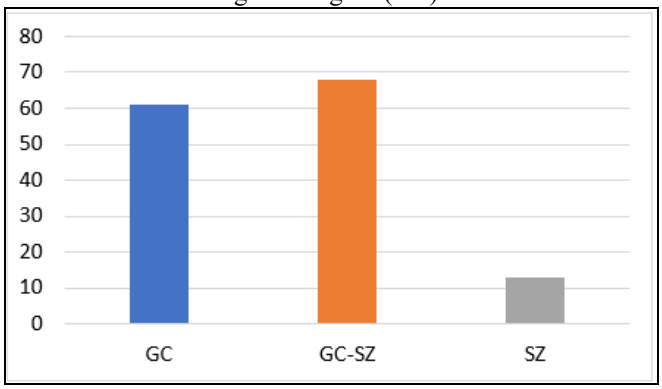
### A. Richness and Floristic Composition

The flora of gallery forests is estimated at 153 species divided into 122 genera and 51 families. The most prevalent families, in order of importance, are Fabaceae, Moraceae, Rubiaceae, Euphorbiaceae, and Sapindaceae (Fig. 2).




**[Fig.2: Distribution of Species by Family]**

Considering the phytogeographic origin of each species, it can be seen that species from the transition zone (GC-SZ) are the most numerous (Fig. 3). They are followed by species from the Guineo-Congolese region (GC)




**[Fig.3: Phytogeographic Distribution of Species]**

**Legend**: GC: Taxon from the Guineo-Congolese region; GC-SZ: Taxon from the transition zone between the

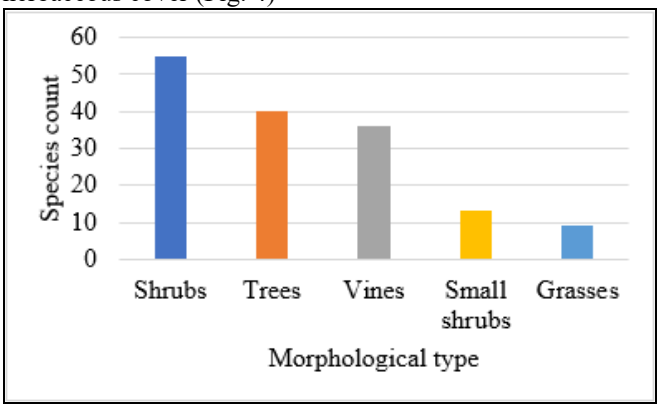
*Retrieval Number: 100.1/ijb.A107106010426*
*DOI: 10.54105/ijab.A1071.06010426*
*Journal Website: www.ijb.latticescipub.com*



*Published By:*
*Lattice Science Publication (LSP)*

Guineo-Congolese and Sudano-Zambezi regions; SZ: Taxon from the Sudano- Zambesian region.

Analysis of the distribution of growth forms reveals a predominance of shrubs (55 species), followed by trees (40 species) and vines (36 species). Small shrubs (13 species) and grasses (9 species) are poorly represented. This structure reflects vegetation dominated by woody plants, with a notable contribution from climbing plants and relatively low herbaceous cover (Fig. 4)




**[Fig.4: Distribution of Species According to Biological Types]**

### B. Characteristic Species of Gallery Forests

The characteristic species of gallery forests are *Berlinia grandiflora* (Vahl) Hutch. & DaIz., *Carapa procera* DC. De Wilde, *Cola gigantea* A. Chev. var. glabrescens Brenan & Keay, *Cola laurifolia* Mast., *Dialium guineense* Willd., *Lecaniodiscus cupanioides* Planch., *Ochna membranacea* Oliv., *Olax subscorpioidea* Oliv., *Synsepalum brevipes* (Baker) T. D. Penn., *Phoenix reclinata* (Table I). These species recur regularly in floristic surveys.

**Table I: List of Characteristic Species of Gallery Forests**

| N° | Species | Family |
|---|---|---|
| 1 | *Berlinia grandiflora* (Vahl) Hutch. & DaIz. | Fabaceae |
| 2 | *Carapa procera* DC. De Wilde | Meliaceae |
| 3 | *Cola gigantea* A. Chev. var. glabrescens Brenan & Keay | Malvaceae |
| 4 | *Cola laurifolia* Mast. | Malvaceae |
| 5 | *Dialium guineense* Willd. | Fabaceae |
| 6 | *Ficus sur* Forsk. | Moraceae |
| 7 | *Ficus sycomorus* L. | Moraceae |
| 8 | *Lecaniodiscus cupanioides* Planch. | Sapindaceae |
| 9 | *Ochna membranacea* Oliv. | Ochnaceae |
| 10 | *Olax subscorpioidea* Oliv. | Olacaceae |
| 11 | *Synsepalum brevipes* (Baker) T. D. Penn. | Sapotaceae |
| 12 | *Elaeis guineensis* Jacq. | Arecaceae |
| 13 | *Phoenix reclinata* Jacq. | Arecaceae |

### C. Endemic and/or Endangered Species Found in Gallery Forests

Several endangered or restricted-range species find refuge in the gallery forests of the sub-Sudanian region (Table II). These include species endemic to the West African forest block (GCW) and those listed by the IUCN and Aké-Assi, respectively, as vulnerable (VU) or rare species facing extinction (PRE).

**Table II: List of Species with Special Status Encountered**

| N° | Specie | Family | Endemism | Ake-Assi Status | IUCN Status |
|---|---|---|---|---|---|
| 1 | *Afzelia africana* Sm. | Fabaceae | - | | VU |
| 2 | *Ansellia africana* Lindl. | Orchidaceae | - | | VU |
| 3 | *Cola caricaefolia* (G. Don) K. Schum. | Malvaceae | GCW | - | - |
| 4 | *Combretum comosum* G. Don | Combretaceae | GCW | - | - |
| 5 | *Dalbergia oblongifolia* G. Don | Fabaceae | GCW | - | - |
| 6 | *Eriocoelum pungens* Radlk. ex Engl. | Sapindaceae | GCW | - | - |
| 7 | *Eugenia salacioides* G.Lawson ex Hutch. & Dalziel | Myrtaceae | GCW | - | - |
| 8 | *Gaertnera paniculata* Benth. | Rubiaceae | GCW | - | - |
| 9 | *Garcinia afzelii* Engl. | Clusiaceae | - | PRE | VU |
| 10 | *Milicia excelsa* (Welw.) Benth. | Moraceae | - | *PRE* | - |
| 11 | *Pavetta lasioclada* (K. Krause) Mildbr. ex Bremek. | Rubiaceae | - | - | VU |
| 12 | *Xylopia elliotii* Engl. & Diels | Annonaceae | GCW | PRE | - |

**Legend**: **GCW**: Endemic species of West Africa; **PRE**: Rare and/or endangered plant; **VU**: Vulnerable

## IV. DISCUSSION

The estimated 153 species reflect a relatively high level of floral diversity. This result is consistent with the observations of [9] which emphasize that gallery forests are islands of high plant diversity within the Sudanian domain. Thus, these formations serve as refuges for many forest species.

The predominance of Fabaceae, Moraceae, Rubiaceae, Euphorbiaceae, and Sapindaceae is consistent with the results of studies conducted in sub-Sudanian areas by [5] These families, mainly represented by taxa with a wide ecological range, are recognized as those that characterize all Ivorian forests [2], [10]. As such, their predominance is not unique to the gallery forests of the sub-Sudanian region. Their presence reflects the gallery forests in this region's capacity to support species that are both light-tolerant and adapted to constant soil moisture. Furthermore, the high proportion of Rubiaceae indicates that the sampled gallery forests have not yet reached the climax stage [1].

A comparative analysis of the dominant botanical families in sub-Sudanese gallery forests between 1971 and 2025 highlights three major evolutionary groups. The resilient families present and dominant in both periods are mainly represented by

Fabaceae, Rubiaceae, Moraceae, and Annonaceae, which constitute the stable floristic core of these riparian formations. The families in decline, which were abundant in the 1971 inventories but have become rare in 2025, include Euphorbiaceae, Sterculiaceae, and Meliaceae, reflecting increased sensitivity to anthropogenic disturbances and habitat fragmentation. Conversely, emerging families, which were poorly represented or absent in older inventories but are now among the most important, include Apocynaceae, Sapindaceae, and Combretaceae, reflecting a gradual floristic recomposition in favour of taxa more tolerant of altered ecological conditions.

The high proportion of shrubs, followed by trees and vines, illustrates a plant structure dominated by secondary stages. This structural profile, consistent with the results of [9], could result from anthropogenic pressures such as bush fires, grazing, and selective logging, which are often found in gallery forests in the sub-Sudanian zone. Despite these disturbances, the presence of typical species such as *Berlinia grandiflora*, *Carapa procera*, *Cola laurifolia*, *Dialium guineense*, and *Phoenix reclinata* confirms the forest character of these formations. Since the last studies, these taxa have been considered ecological indicators of transitional humid gallery forests. A comparison between the current flora and that inventoried in 1971 reveals a significant decline in species diversity, accompanied by a structural simplification of the vegetation. Of the many species recorded in the first inventories, only *Anthostema senegalense*, *Berlinia grandiflora*, *Bridelia speciosa*, *Embelia djalonensis*, *Gardenia sokotensis*, *Mimosa pigra*, *Raphia sudanica*, and *Samanea dinklagei* are common to both periods, reflecting a strong capacity for ecological resilience in the face of environmental and anthropogenic disturbances. Other species that are tolerant to disturbances and have a wide ecological range, such as *Elaeis guineensis*, *Ficus sur*, *Ficus sycomorus*, and *Phoenix reclinata,* complete this flora. The arrival of these species in gallery forests reflects the advanced level of anthropisation of riparian ecosystems.

In contrast, the majority of species previously reported, including *Paramacrolobium coeruleum*, *Sorindeia juglandifolia, Connarus thonningii, Rourea minor, Aegle marmelos, Canscora alata, Canscora diffusa, Garcinia ovalifolia, Saba thompsonii, Aristolochia goldieana, Stephanotis abyssinica, Cordia guineensis, Psophocarpus monophyllus, Cremaspora trifloral, Mussaenda arcuate, Oldenlandia wauensis*, and *Clerodendrum mannii*, have not been found in the current flora, suggesting their local extinction or extreme rarity. These species, generally dependent on well-preserved wetlands, seem particularly sensitive to the degradation of gallery forests.

Beyond the simple loss of species, this trend reflects a functional alteration of gallery forests, likely to have a lasting impact on their ecological roles, particularly in riverbank protection, water regulation, and the conservation of local biodiversity.

The majority of species in the transition zone (GC-SZ) confirm the observations of [9]. This finding demonstrates the ecological role these forests play as corridors. They ensure floristic continuity between the dense formations of the south and the savannas of the north. This floristic transition is well documented by [7], who describe gallery forests as areas of floristic mixing where forest, mesophilic, and heliophilic species coexist.

Finally, the presence of several endangered species in these gallery forests underscores their high conservation value. These refuges often represent the last viable habitats for certain relict forest species in savanna areas. Their conservation is therefore a major ecological priority, as these ecosystems help maintain ecological connectivity and the resilience of savanna landscapes in the face of climate change and anthropogenic fragmentation.

## V. CONCLUSION

The flora of gallery forests is estimated at 153 species divided into 122 genera and 51 families. The most prevalent families, in order of importance, are Fabaceae, Moraceae, Rubiaceae, Euphorbiaceae, and Sapindaceae. A comparison of the botanical families of sub-Sudanian gallery forests between 1971 and 2025 reveals a resilient floristic core dominated by Fabaceae, Rubiaceae, Moraceae, and Annonaceae. On the other hand, formerly abundant families such as Euphorbiaceae, Sterculiaceae, and Meliaceae show a clear decline, while Apocynaceae, Sapindaceae, and Combretaceae appear as emerging families. It should be noted that species in the transition zone (GC-SZ) are the most numerous. Shrubs are the most prevalent, followed by trees and vines. Characteristic species of gallery forests are *Berlinia grandiflora* (Vahl) Hutch. & DaIz., *Carapa procera* DC. De Wilde, *Cola gigantea* A. Chev. var. glabrescens Brenan & Keay, *Cola laurifolia* Mast., *Dialium guineense* Willd., *Lecaniodiscus cupanioides* Planch., *Ochna membranacea* Oliv., *Olax subscorpioidea* Oliv., *Synsepalum brevipes* (Baker) T. D. Penn., and *Phoenix reclinata*. A diachronic analysis of the flora of sub-Sudanese gallery forests reveals a marked decline in species diversity since the 1971 inventories. This trend has led to the local disappearance of many hygrophilous species, replaced by a flora dominated by taxa tolerant of disturbance. Several endangered species find refuge in the gallery forests of the sub-Sudanian region.

## VI. ACKNOWLEDGMENT

The authors would like to thank the reviewers for their constructive comments, which significantly improved the quality of the manuscript.

## DECLARATION STATEMENT

As the article's author, I must verify the accuracy of the following information after aggregating input from all authors.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been funded by any organizations or agencies. This independence ensures that the research is conducted objectively and without external influence.

- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate with supporting documentation.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is contributed equally to all participating individuals.

## REFERENCES

1. Claude, J. P., Joseph, P., Abati, Y., Major, P., Jean-Francois, Y., Ely-Marius, S., & Sophie, S. Considerations on the ecology of Rubiaceae in Martinique (Lesser Antilles). *Eco. Env. & Cons*, **29** (3), 1001–1023 (2023). DOI: http://doi.org/10.53550/EEC.2023.v29i03.001
2. Kambaj, O. K., Sershen, G. Y., & Ramdhani, S. A floristic cozmparison of three Northern Coastal Forests differing in disturbance history. Bothalia, 48 (1), a2262 (2018). DOI: https://doi.org/10.4102/abc.v48i1.2262
3. Mehvar, S., Filatova, T., Dastgheib, A., De Ruyter van Steveninck, E., & Ranasinghe, R. Quantifying economic value of coastal ecosystem services: a review. *Journal of marine science and engineering*, **6**(1), 5. (2018). DOI: https://doi.org/10.3390/jmse6010005
4. N'Guessan, A. E., N'dja, J. K., Yao, O. N., Amani, B. H., Gouli, R. G., Piponiot, C., & Hérault, B. Drivers of biomass recovery in a secondary forested landscape of West Africa. *Forest Ecology and Management*, *433*, 325-331 (2019). DOI: https://doi.org/10.1016/j.foreco.2018.11.021
5. Aleman, J. C., Jarzyna, M. A., & Staver, A. C. Forest extent and deforestation in tropical Africa since 1900. Nature Ecology & Evolution, 2, 26–33 (2018). DOI: https://doi.org/10.1038/s41559-017-0406-1
6. Sabi Lolo Ilou B., Sogbohossou E. A., Toko Imorou I., Houinato M. R. B., Sinsin B., 2017. Diversité et importance socio-économique des services écosystémiques dans la réserve de biosphère de la Pendjari, au nord du Bénin. Journal de la Recherche Scientifique de l'Université de Lomé, 19 (3) : 15-28. https://www.ajol.info/index.php/jrsul/article/view/167462
7. Taonda, A., Zerbo, I., N'Guessan, A. E., Traoré, I. C. E., Kassi, J. N., & Thiombiano, A. Effects of land use and climate on the diversity and population structure in natural stands of Detarium microcarpum Guill. & Perr. (Fabaceae) in Burkina Faso (West Africa). Global Ecology and Conservation, 51, e02909 (2024). DOI: https://doi.org/10.1016/j.gecco.2024.e02909
8. UICN, Liste rouge des espèces menacées. https://www.iucnredlist.org/fr/resources/regionalguidelines (2026).
9. Yao, N. O., N'Guessan, A. E., Egnankou, W. M., Sangare, M. & N'Guessan, K. E. Structure et composition de la végétation en zone subsoudanaise (Département de Dianra, Nord-Ouest de la Côte d'Ivoire) : étude descriptive et comparative. *Afrique* SCIENCE 14(2), 304 – 315 (2018). http://www.afriquescience.info.
10. Yéo, Z. S., Sangne, Y. C., Barima, Y. S. S., Bamba, I., Kouakou, K. A. Diversité floristique et structure des fragments forestiers du Sud-Ouest du parc national de la Comoé après les conflits des années 2000 en Côte d'Ivoire. *European Scientific Journal*, **13** (2), 421- 439 (2017). DOI: https://doi.org/10.19044/esj.2016.v13n2p421

## AUTHOR'S PROFILE

**KOUADIO Yao Jean-Clovis** is an Ivorian ecologist and environmentalist, currently an assistant professor at Félix Houphouët-Boigny University in Abidjan. He holds a PhD in forestry (2016) from the same university. His academic training is complemented by specialised certifications in environmental economics, sustainable development, environmental assessment, statistics, spatial analysis, and R data analysis. His research focuses on plant biodiversity in both urban and natural environments. He has contributed extensively to benchmark environmental studies, biodiversity inventories, and ecosystem restoration programs throughout Côte d'Ivoire. Dr. Kouadio is the author of several scientific publications related to biodiversity conservation. He is an active member and contributor to the Clearing House Mechanism (CHM), a platform dedicated to biodiversity information. Dr. KOUADIO Yao Jean-Clovis combines academic rigor with solid field expertise, making him a recognized professional in the fields of biodiversity enhancement, sustainable development, and environmental assessment of projects and programs in Côte d'Ivoire.

**POUNDA Nomel Gnagne Jules Richard** is a lecturer and researcher at the École normale supérieure d'Abidjan in Côte d'Ivoire. He is a specialist in plant biology and holds a PhD in urban forestry, earned in 2020 upon the successful defence of his doctoral thesis. His research focuses on the analysis of urban forests, particularly school green spaces. His expertise covers the selection of resilient species, phytosanitary diagnosis, and the economic evaluation of urban forest ecosystem services. He is the author of several scientific articles based on studies conducted in Côte d'Ivoire's green spaces.

**MEVANLY Ouattara** holds a PhD in Ecology and Botany. He is an Assistant Professor in the Natural Environments and Biodiversity Conservation laboratory of the first and most prestigious University of Côte d'Ivoire. He belongs to the Pedagogical Research Unit of Botany, where he supervised Master's students in Urban Forestry and Wetland Ecology. With 6 years of experience, he has been striving for the past 2 years to serve the university and local communities by leading conferences on the role of green spaces in establishing sustainable cities and the importance of wetlands to local populations. With a view to advancing international scientific research, he is committed to writing and to actively participating in research projects and supervising students worldwide.