

Floristic diversity, composition and biomass of neglected riparian forests in Southern Côte d'Ivoire

Bi Tra Aimé Vroh^{1*} , Kouassi Bruno Kpangui² , and Abdoulaye Cissé¹ 

¹UFR Biosciences, University of Félix Houphouët-Boigny, Côte d'Ivoire.

*E-mail: vrohbitra@gmail.com

²UFR Environnement, University of Jean Lorougnon Guédé, Côte d'Ivoire.

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Abstract

With the loss of most of Côte d'Ivoire's forests, it is time to focus conservation and protection strategies on the remaining fragments scattered throughout agro-systems. However, these forests remain neglected and little known in terms of their value for biodiversity conservation. The aim of this study was to report the overall ecological value of different fragments of riparian forests scattered in the agro-systems of Southern Côte d'Ivoire. The level of floristic diversity, the conservation interest of these forests, the structural characteristics of the vegetation and the aboveground biomass were assessed. Trees with a diameter of at least 2.5 cm were counted in 222 plots in dry-land forests and periodically or permanently flooded forests. Qualitative and quantitative diversity indices, density and aboveground biomass were calculated. The results showed that these forests are home to 267 species, 94 % of which are present in dry-land forests, compared to 28–32 % in permanently and periodically flooded forests, respectively. The high abundance of *Alchornea cordifolia* (18 to 23 % of the stems) leads to an imbalance in the distribution of stems between species. Despite the low levels of aboveground biomass (5.6 to 20.3 t·ha⁻¹), the abundance of species from the Guinean-Congolese phytogeographic region (67.10 to 75.3 %) and the presence of 37 rare, threatened and/or endemic species are encouraging signs for the conservation of these remnant forests. These forests therefore deserve a census and the development of a specific strategy for their conservation.

Key words: conservation value, flooded forest, remnant forest, secondary landscape, West Africa.

Introduction

The West African rainforests are considered to be rich ecosystems with complex structures containing many endemic species (Sayer et al. 1992). They have been described as one of the most important biodiversity hotspots hosting rare and/

or threatened species (Holmgren et al. 2004).

In this part of Africa, the territory of Côte d'Ivoire has been historically explored by botanists, who described the southern coastal zone as a dense evergreen humid forest (Aké Assi and Pfeffer 1975). These floristic studies have shown that the flora

of the forests of Southern Côte d'Ivoire is highly diverse.

In order to preserve this floristic heritage, the Ivorian government has created a network of protected areas (national parks and reserves) and classified forests throughout the country. In this southern zone, the Taï, Azagny and Ehotilé Island National Parks and the Tanoé-Ehy Marshes Voluntary Nature Reserve contain relatively exclusive flora in terms of the endemism that characterises them (Poorter et al. 2004). In contrast, much of the classified forest in the Southern Forest has been invaded by farmers who are clearing it to grow cash crops, such as cocoa, rubber and oil palm. Outside protected areas and classified forests, the situation is alarming in rural areas, where large-scale industrial oil palm and rubber plantations have developed alongside family plantations run by local farmers, leading to the loss of almost all forest cover in the south (Landrot and Dufour 2015).

The result of this loss of forests in the rural areas of Southern Côte d'Ivoire has been their gradual replacement by agricultural land and degraded riparian forests. This riparian vegetation includes secondary forests, the plant communities of watercourses, riverbanks and floodplains, and is an integral part of river ecosystems. There are degraded forest fragments, isolated and more or less heavily exploited. They appear in the secondary landscape after deforestation. Due to their state of degradation, these forests have numerous lianas with a discontinuous megaphanerophytic layer. In fact, in this rural area of the south of Côte d'Ivoire, the extraction of precious woods leads to a total depletion and the vegetation, except for a few emergents, resembles a secondary thicket (Chatelain et al. 1996). Elsewhere, these types of riparian forests have been

shown to be diverse in terms of animal and plant species, vegetation stratification and regeneration processes (Maingi and Marsh 2006). These forests represent a unique biological community adapted to anthropogenic disturbance (Ledec 1987). They are also considered biodiversity corridors (Corbacho et al. 2003), which provide the maintenance of ecological functions between terrestrial and aquatic areas (Hitoshi and Toshikazu 2008). In Côte d'Ivoire, however, these forests are little known. They are not often part of strategic priorities for biodiversity conservation. Despite the degradation of these riparian forests, a pragmatic approach to the conservation of flora and fauna in the area is urgently needed.

In January 2019, Côte d'Ivoire embarked on a national forest and wildlife inventory (NFI) to obtain the strategic information needed to continue public action and provide the sustainable management of these resources (Cuny et al. 2023). This approach was intended to provide the basis for the implementation of its strategy for the conservation, rehabilitation and expansion of forests. The NFI was also established to halt the loss of genetic resources and to address the challenges faced by industries and communities in accessing wood and wood energy. However, this NFI provided very little specific information on the quality of these riparian and/or community forests scattered in rural areas. Yet, Law No. 2019-675 of 23 July 2019 on the Forestry Code of the State of Côte d'Ivoire provides for the official registration of these rural community forests and tools for their management (regulations and incentives, committees and simple management plans).

In the dynamic promoted by the Forestry Code, it is essential to demonstrate the quality of these riparian forests in terms

of biodiversity conservation. Indeed, detailed knowledge of the floristic composition and diversity of plant species in these forests is the first step towards their conservation. In order to formulate policies to manage species decline and to control the ecological drivers of change, it is important to determine the status of the species present in these riparian forests, whether they are anthropophilic, rare, threatened, abundant or endangered.

This study, therefore, aims to report on the overall ecological value of different fragments of riparian forests scattered in the agro-systems of Southern Côte d'Ivoire. Specifically, the study made it possible to assess the level of floristic diversity of riparian forests, to analyse the conservation interest of these forests, to characterise the vegetation stratification, to estimate the aboveground biomass of trees and to analyse the relationships between

these different diversity parameters, the biomass and the density of trees in these riparian forests.

Materials and Methods

Study area

The study was conducted in the rural area of the Southern Forest of Côte d'Ivoire (Fig. 1). This area is located in the domain of evergreen forests and the Guineo-Congolese phytogeographic region. This area corresponds to the centres of heavy rainfall: 1500 to 2000 mm of rain per year (Konaté et al. 2023). The area is characterised by a generally low relief. The soils are of the desaturated ferralitic type (Kouamé and Zoro 2010). The hydrographic network is immense, dominated by coastal lagoons, the Bandama and Comoé rivers (to the south-east),

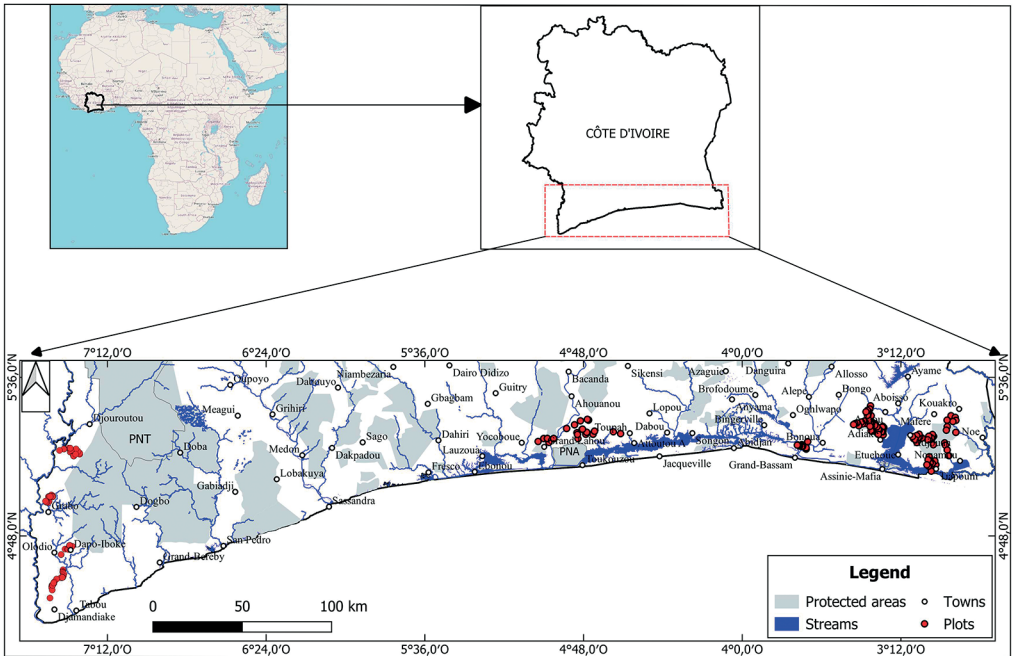


Fig. 1. Location of study area and inventory plots.

the Sassandra and Cavally rivers (to the south-west) and numerous small streams scattered throughout the agro-systems.

The area is dominated by rubber and oil palm plantations owned by agro-industrial companies, such as PALMCI, SAPH and SOGB. These companies work with the villagers and supervise the creation of village rubber and/or oil palm plantations.

In addition to classified forests and protected areas, this mosaic of land use includes unprotected and uncultivated plant formations owned by rural communities. The studied riparian forests are divided into three categories: dry-land forests, permanently flooded forests and periodically flooded forests. These different riparian formations were considered and compared in this study.

Data collection

Data were collected in 222 circular plots of 500 m² (11.1 ha in total). These plots were established in three forest types: dry-land forests ($N = 84$), periodically flooded forests ($N = 67$) and permanently flooded forests ($N = 71$).

For this study, to be considered 'forest', the habitat had to meet the definition of a forest in Côte d'Ivoire adopted in 2014: the surface area must be greater than or equal to 0.1 ha, the tree cover must be greater than or equal to 30 % and the height of mature trees must be greater than or equal to 5 m (République de Côte d'Ivoire 2019). Habitats that did not meet this definition were not considered.

In each plot, individual trees with a diameter at breast height (DBH) of at least 2.5 cm were counted. This minimum diameter allowed the inclusion of adult trees, saplings and young plants (Abdourhamane et al. 2017), which also maximises diversity (Vroh et al. 2010). The heights

of these trees were also measured. Tree species were considered because it has been shown that an inventory of these species can provide sufficient information on abundance and diversity, which are useful tools for plant conservation (Egbe et al. 2021).

The majority of species were identified in the field. For undetermined species, identification guides to the flora of the studied area were consulted (Hawthorne and Jongkind 2006). The POWO (2025) database was used to check the scientific names.

Data analysis

Floristic and ecological analyses

Species diversity was estimated using two facets: 'species richness' and 'species evenness' (Magurran and Phillip 2001). Species richness (S) was determined by counting the species recorded in the inventoried plots. Three non-parametric richness estimators were calculated to assess the completeness of the inventories: Chao 1 (Chao 1984); Jackknife 1 and Jackknife 2 (Burnham and Overton 1978). Evenness was measured by Pielou index (Pielou 1966) for each habitat. Species diversity was calculated by Shannon index (Shannon 1948). The Shannon index and Pielou's index were calculated using formulas (1) and (2).

$$H = -\sum_i^S p_i \cdot \ln p_i, \quad (1)$$

$$J = \frac{H}{\ln S}, \quad (2)$$

where: H = Shannon index, J = Pielou's index, S = species richness, p_i = relative abundance of species i , $\ln$ = natural logarithm.

A Venn diagram was constructed to as-

sess the degree of similarity between the different forest types. The graph allowed us to compare the floristic composition shared by these three forest types and the number of species unique to each.

To assess the ecological importance, species patterns were compared graphically through ranking of abundance. For each forest type, the abundance (N) of species was transformed to logarithm $10(N + 1)$ and the tabulated data from the most abundant species to the least abundant (Feinsinger 2001).

The conservation value of the different forest types was assessed by identifying species endemic to West African forests (White 1983) and threatened species on the IUCN Red List (2024).

Stem densities were calculated for each plot and averages were calculated for each forest type. Taking into account the diameter classes, stem distribution histograms were constructed and their shape allowed an assessment of the self-regeneration rate of the forests.

The pantropical allometric equation developed by Chave et al. (2014) was used to estimate aboveground biomass (AGB). This equation is considered to be more robust, recent, covers a wide range of vegetation types and incorporates data from other pantropical equations, such as the Chave et al. (2005) and Fayolle (2013) equations. The mathematical expression of this allometric is represented by equation (1).

$$\text{AGB} = 0.0673 \cdot (r \cdot \text{DBH}^2 \cdot H)^{0.976}, \quad (3)$$

where: AGB is the estimated aboveground biomass, kg; r is the specific density of wood, $\text{g} \cdot \text{cm}^{-3}$; DBH is the diameter at breast height, cm; H is the total height of the tree, m.

For biomass estimation, the minimum diameter considered was 5 cm (DBH $\geq$

5 cm), as recommended by Chave et al. (2014).

Statistical analysis

Analyses of variance (ANOVA) were used to compare the means of diversity parameters (species richness, Shannon, evenness), tree density and aboveground biomass between forest types. Principal component analysis (PCA) was used to test the relationships between these different parameters (richness, Shannon, evenness, density and aboveground biomass). The robustness of the relationships (according to the p -value) and the direction (negative or positive) between these parameters were assessed using Pearson correlation tests. These tests allowed us to verify the hypothesis that there is a common positive correlation between diversity, richness and biomass in *in situ* forests (Sintayehu et al. 2020). All calculated diversity indices and statistical analyses were performed using the program R4.3.1 (R Core Team 2023).

Results and Discussion

Floristic richness and diversity in the three habitat types

The number of stems (DBH ≥ 2.5 cm) was 15,435 individuals in the three habitat types. These stems were divided into 267 species. Comparing this finding, the studied habitats are less rich than those of the Monogaga Classified Forest with 296 species (Adou Yao et al. 2011), the Ehotilé Islands National Park with 315 species (Malan et al. 2007) and the Forêt Marais Tonoé-Ehy Reserve with 568 species (Abrou et al. 2019). On the other hand, it is higher than the tree richness (127 spe-

cies) of the Azagny National Park, an area dominated by swamps (Adiko et al. 2020).

If we take the habitats separately, the number of species is higher in dry-land forests ($S = 251$ species) than in the other two habitat types ($S = 77$ and 86 for permanently and periodically flooded forests, respectively). The three habitat types together account for 54 species or 20.2% of the species present (Fig. 2). Dry-land forests and periodically flooded forests are more similar (75 species, 28.1%). Conversely, periodically flooded forests are less similar to permanently flooded forests (20.6% of species in common). This finding may explain the relatively low similarity between the three habitat types, which reflects a high degree of floristic heterogeneity in the area as argued by Menino

et al. (2012). However, this similarity was based on sampled species only.

According to the estimators (Chao 1, Jackknife 1 and Jackknife 2), the sampling completeness in dry-land forests is 66.5 to 76.9% , i.e. 75 to 126 species were not observed (Table 1). In the other two forest types, 76 to 95% of the species were sampled. These results indicate that there are many more rare species (singletons and doubletons) in the dry-land forests. The similarity between dry-land forests and the other two forest types will be even lower in the case of exhaustive sampling. In the other two forests, only 3 to 26 species were not observed, indicating that sampling tends to be exhaustive in these habitats, which are constrained by the presence of water.

The average values of richness and Shannon index show also that species diversity is higher in dry-land forests than in the other two habitat types (Fig. 3). Indeed, the average richness per 500 m^2 plot is ~ 16 species in dry-land forests. However, it varies between 8 and 10 species in the other two types of forest. On the other hand, the three habitat types have the same species evenness.

The low species diversity in flooded forests can be explained by the fact that these habitats are subject to special conditions (permanent or temporary flooding), which make them favourable for some specialised species and unfavourable for a large diversity of species that colonise dry forests. Parolin et al. (2010) have also

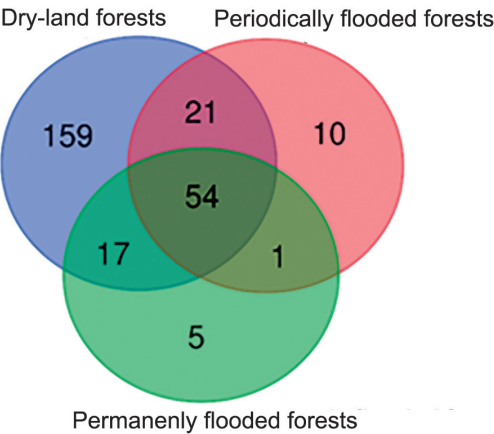


Fig. 2. Distribution of the number of species between the three forest types.

Table 1. Floristic richness observed and estimated in the different forest types.

Forest type	Richness observed	Richness estimates		
		Chao 1	Jackknife 1	Jackknife 2
		number of species		
Dry-land forests	251	368.2	326.0	377.0
Periodically flooded forests	86	107.3	102.0	112.0
Permanently flooded forests	77	80.6	83.0	84.0

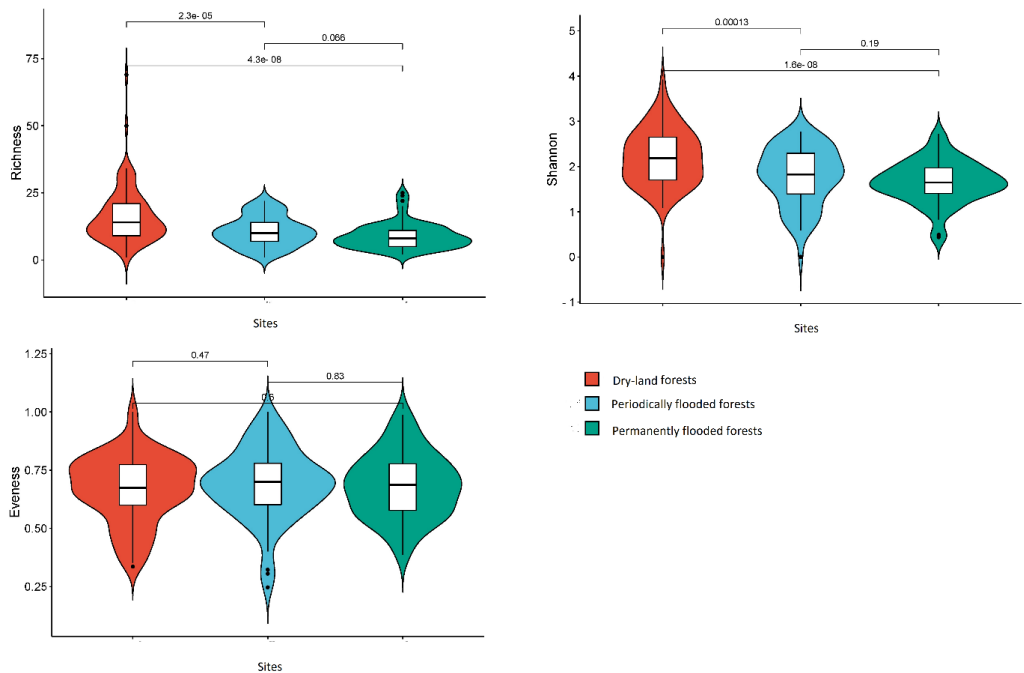


Fig. 3. Comparison of mean values of specific diversity parameters.

Note: The violin plots combined with summary statistics (mean $\pm$ SD) and box plots. The numbers above the violin plots indicate the p-values for comparing means in pairs (Tukey test): if the p-value is less than 0.05, the means are significantly different.

shown that plant diversity tends to be low in these water-stressed environments due to the environmental constraints associated with soil saturation.

Floristic composition

Alchornea cordifolia (Shum. & Thonn.) Müll. is the most abundant species in all habitats (Fig. 4): 20, 18.2 and 22.6 % of the stems in dry-land forests, periodically flooded and permanently flooded forests respectively. The high abundance of *A. cordifolia* could reflect a low homogeneity in the distribution of stems between the species recorded. This finding is consistent with that of Kurtz et al. (2015), who showed that *A. cordifolia* is therefore bet-

ter adapted to these anthropised forest types. This species, which has a wide distribution in the Guineo-Congolese tropical forest zone, is abundant in habitats with high sunlight penetration, such as the forests inventoried in this study (Friis and Harris 2013).

Funtumia africana (Benth.) Stapf (3.5 % of stems) is the second most abundant species in dry-land forests. *Hallea ledermannii* (K. Krause) Verdc. (9.5 % of the stems) and *Macaranga heudelotii* Baill. (7.3 % of the stems) are the most abundant species after *A. cordifolia* in periodically flooded forests. In permanently flooded forests, *H. ledermannii* (13.8 % of the stems) and *Ficus trichopoda* Baker (10.7 % of the stems) are the most abun-

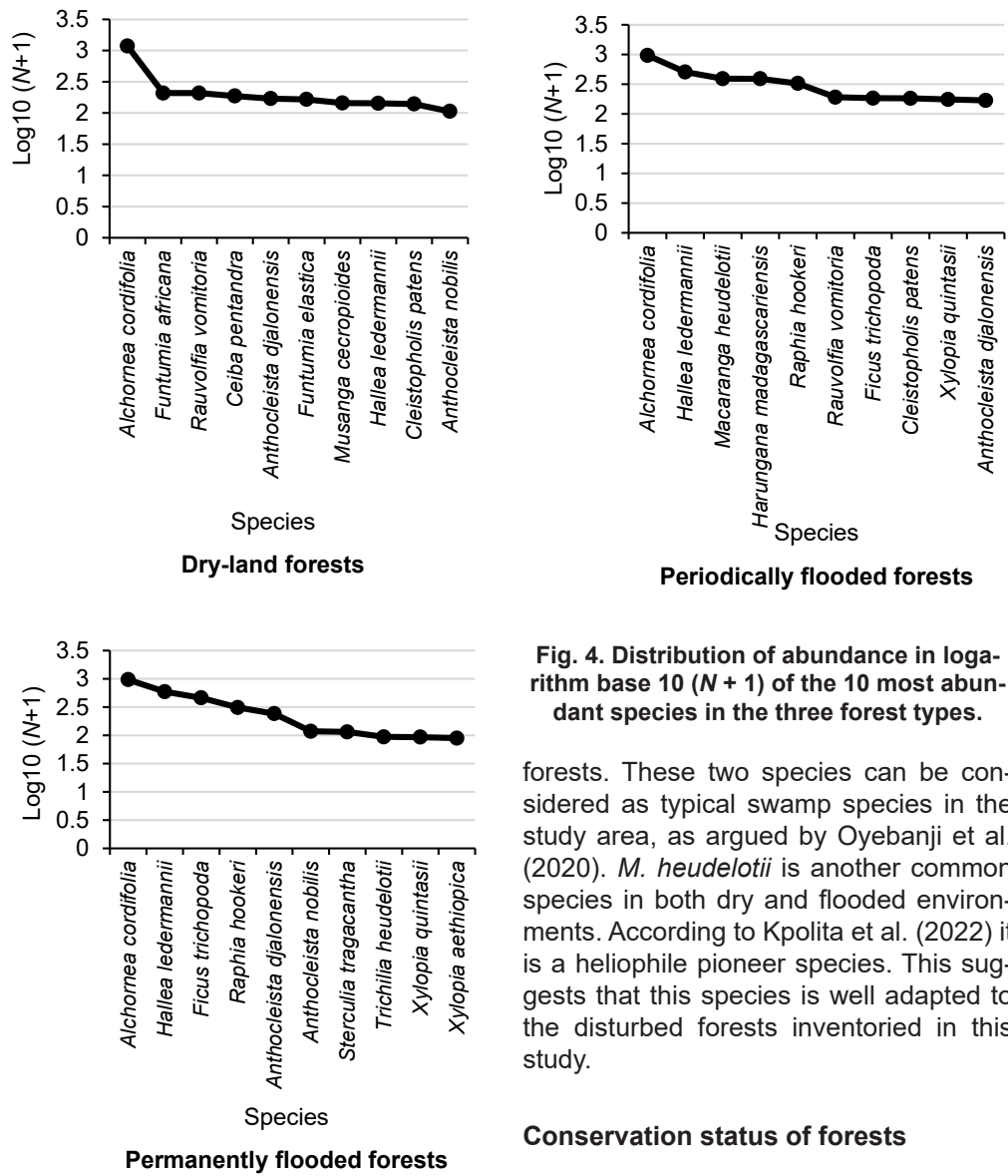


Fig. 4. Distribution of abundance in logarithm base 10 ($N + 1$) of the 10 most abundant species in the three forest types.

forests. These two species can be considered as typical swamp species in the study area, as argued by Oyebojani et al. (2020). *M. heudelotii* is another common species in both dry and flooded environments. According to Kpolita et al. (2022) it is a heliophile pioneer species. This suggests that this species is well adapted to the disturbed forests inventoried in this study.

Conservation status of forests

Of the present species, 24 are on the IUCN Red List, three of which are endangered (*Omphalocarpum ahia* A. Chev., *Dactyladenia hirsuta* (A. Chev. ex De Wild.) Prance & F. White and *Apodiscus chevalieri* Hutch.) and the others are vulnerable (IUCN 2024). The species *O. ahia* was only recorded in permanently flooded

dant species after *A. cordifolia*.
F. africana tends to prefer the degraded dry-land forests inventoried. This result confirms the pioneer-heliophile characteristic of this species, as reported by Carrière (2003). *H. ledermannii* and *F. trichopoda* were only recorded in flooded

forests, while the other two were recorded in dry-land forests (Table 2).

Table 2. Summary of the abundance of species with conservation status in the three forest types.

Species	Family	Conservation status	Dry-land forests	Periodical-ly flooded forest	Permanent-ly flooded forests
			number of stems		
<i>Whitfieldia lateritia</i> Hook.	Acanthaceae	GCW	2	-	-
<i>Anthonota crassifolia</i> (Baill.) J.Léonard	Anacardiaceae	Vu	-	-	2
<i>Antrocaryon micraster</i> A.Chev. & Guill.	Anysophyllaceae	VU / GCW	60	1	-
<i>Cussonia bancoensis</i> Aubrév. & Pellegr.	Araliaceae	Vu	25	-	-
<i>Cordia platythyrsa</i> Baker	Boraginaceae	Vu	16	6	-
<i>Dactyladenia hirsuta</i> (A.Chev. Ex De Wild.) Prance & F.White	Chrysobalanaceae	EN	1	-	-
<i>Magnistipula butayei</i> De Wild.	Chrysobalanaceae	Vu	1	-	-
<i>Garcinia kola</i> Heckel	Clusiaceae	Vu	-	1	-
<i>Terminalia ivorensis</i> A.Chev.	Combretaceae	Vu	9	-	9
<i>Diospyros heudelotii</i> Hiern	Ebenaceae	GCW	-	1	-
<i>Drypetes aubrevillei</i> Leandri	Euphorbiaceae	GCW	33	-	-
<i>Ricinodendron heudelotii</i> (Baill.) Heckel	Euphorbiaceae	Vu	22	4	10
<i>Azelia bella</i> Harms	Fabaceae	GCW	21	-	-
<i>Copaifera salicunda</i> Heckel	Fabaceae	Vu / GCW	4	-	-
<i>Dialium aubrevillei</i> Pellegr.	Fabaceae	GCW	6	-	-
<i>Dracaena fragrans</i> (L.) Ker. Gawl.	Fabaceae	GCW	1	-	-
<i>Millettia lane-poolei</i> Dunn	Fabaceae	GCW	3	-	-
<i>Millettia rhodantha</i> Baill.	Fabaceae	GCW	6	-	-
<i>Anthocleista nobilis</i> G.Don	Gentianaceae	GCW	65	53	84

Species	Family	Conservation status	Dry-land forests	Periodical-ly flooded forest	Permanent-ly flooded forests
			number of stems		
<i>Nesogordonia papaverifera</i> (A.Chev.) Capuron	Malvaceae	Vu	2	-	-
<i>Sterculia oblonga</i> Mast.	Malvaceae	Vu	1	-	-
<i>Entandrophragma angolense</i> (Welw.) C.DC.	Meliaceae	Vu	8	1	4
<i>Entandrophragma candollei</i> Harms	Meliaceae	Vu	1	-	-
<i>Entandrophragma cylindricum</i> Sprague	Meliaceae	Vu	6	-	-
<i>Khaya anthotheca</i> (Welw.) DC.	Meliaceae	Vu	4	-	-
<i>Khaya ivorensis</i> A.Chev.	Meliaceae	Vu	5	-	-
<i>Milicia regia</i> (A.Chev.) C.C.Berg.	Moraceae	Vu / GCW	30	10	6
<i>Lophira alata</i> Banks ex Gaertner	Ochnaceae	Vu	3	-	-
<i>Adenia dinklagei</i> Hutch & Dalz.	Passifloraceae	GCW	1	-	-
<i>Apodiscus chevalieri</i> Hutch.	Phyllantaceae	EN	8	-	-
<i>Anopyxis klaineana</i> (Pierre) Engl.	Rhizophoraceae	Vu	5	-	-
<i>Nauclea diderrichii</i> (De Wild. & T. Duran) Merr.	Rubiaceae	Vu	6	21	10
<i>Zanthoxylum chevalieri</i> Waterm.	Rutaceae	GCW	10	-	-
<i>Placodiscus boya</i> Aubrév. & Pellegr	Sapindaceae	Vu / GCW	1	-	-
<i>Omphalocarpum ahia</i> A.Chev.	Sapotaceae	EN / GCW	-	-	4
<i>Heritiera utilis</i> Sprague	Sterculiaceae	Vu / GCW	-	6	-
Total stems			366	104	129

Note: GCW – endemic to Guineo-Congolian West forests, Vu – vulnerable, EN – endangered species.

Sixteen of the recorded species are endemic to the Guineo-Congolian West forests (GCW). Of these, five are also vulnerable according to the Red List of Threatened Species: *Copaifera salicundata*, *Milicia regia*, *O. ahia*, *Placodiscus boya* and *Heritiera utilis*.

Overall, dry-land forests host more threatened and/or endemic species (35 species) than the other two habitat types (26 species each). The endemic and/or vulnerable species *Anthocleista nobilis*, *Milicia regia*, *Entandrophragma angolense*, *Nauclea diderrichii* and *Ricinodendron heudelotii* are present in all three habitat types (Table 1). All these species are used by rural and urban communities in various ways (seeds for food, timber, etc.), justifying their inclusion on the IUCN Red List of Threatened Species. Some species with a very restricted distribution, such as *Whitfieldia lateritia*, endemic to the hygrophilous forests of western Côte d'Ivoire (Mangenot 1955), are more sensitive to human disturbance (Iralu et al. 2020) and deserve special attention for their conservation. As confirmed by Tchouto (2004), the presence of these

rare, endemic and/or threatened species in these habitats, often considered to be of low ecological value for conservation, is an indication that they deserve to be included in national biodiversity conservation policies and/or strategies.

Density, biomass and structure of the vegetation

The mean density of all stems (DBH ≥ 2.5 cm) varies from 379.5 stems $\cdot$ ha $^{-1}$ in dry-land forests to 486.7 stems $\cdot$ ha $^{-1}$ in permanently flooded forests (Fig. 5). The difference between these mean densities is significant (ANOVA: p -value = 0.024). Considering only trees over 10 cm DBH, the densities ranged from 254 stems $\cdot$ ha $^{-1}$ in periodically flooded forests to 189 stems $\cdot$ ha $^{-1}$ in dry-land forests. According to Pascal (2003), stem density (DBH > 10 cm) in tropical forests is between 450 and 750 stems $\cdot$ ha $^{-1}$. According to the same author, in forests without particular constraints, the average is around 600 stems $\cdot$ ha $^{-1}$. We can therefore say that none of the studied forests tended to have the high stem density found in undisturbed

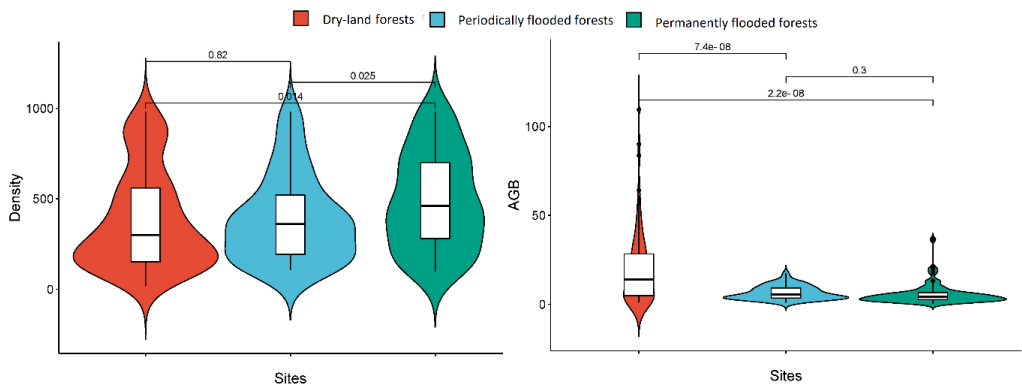


Fig. 5. Comparison of average density and aboveground biomass of inventoried forests.

Note: The violin plots combined with summary statistics (mean $\pm$ SD) and box plots. The numbers above the violin plots indicate the p -values for comparing means in pairs (Tukey test): if the p -value is less than 0.05, the means are significantly different.

forests. This means that the three types of forest have specific constraints that have a significant impact on tree density.

Aboveground biomass (AGB) is also higher in dry-land forest ($20.3 \text{ t}\cdot\text{ha}^{-1}$) and lower in the other two habitat types (6.4 to $5.6 \text{ t}\cdot\text{ha}^{-1}$). The post-hoc test shows a significant difference between the means of AGB in dry-land forests and the other two forest types, but the latter are not significantly different (Fig. 5). These aboveground biomass values are very low compared to the reference values defined by Lewis et al. (2013) in 12 African countries. In fact, according to these authors, the aboveground biomass varied between 240 and $426 \text{ t}\cdot\text{ha}^{-1}$ in the south of Côte d'Ivoire. This observation may be linked to the fact that the studied forests, which are not protected areas, are subject to various forms of exploitation, including the collection of non-timber forest products, the extraction of wood for the construction of canoes and buildings, and firewood.

The distribution of stems according to diameter classes shows that in all forest types the majority (47 to 53 %) of the in-

dividuals recorded have a diameter between 2.5 and 10 cm (Fig. 6). For larger diameter classes, stem density gradually decreases, giving all distribution histograms an 'inverted J' shape. In particular, in periodically flooded and permanently flooded forests, stems with a diameter greater than 60 cm are almost absent (less than 1 % of individuals). The 'inverted J' shape reflects the relative stability of the inventoried habitats, as reported by (Kakaï et al. 2016). Indeed, the abundance of stems with diameters between 2.5 and 10 cm reflects a strong regeneration potential (Koné and Vroh 2021). This regeneration seems to be more important in permanently flooded and periodically flooded forests, if we consider the stem densities in diameter classes less than 20 cm . On the other hand, species that can reach more than 20 cm in diameter are less present in these forests under the constraint of the presence of water. For example, *Alchornea cordifolia*, which represents up to 23 % of the stems in these flooded forests, is a species whose individuals do not reach 20 cm in diameter.

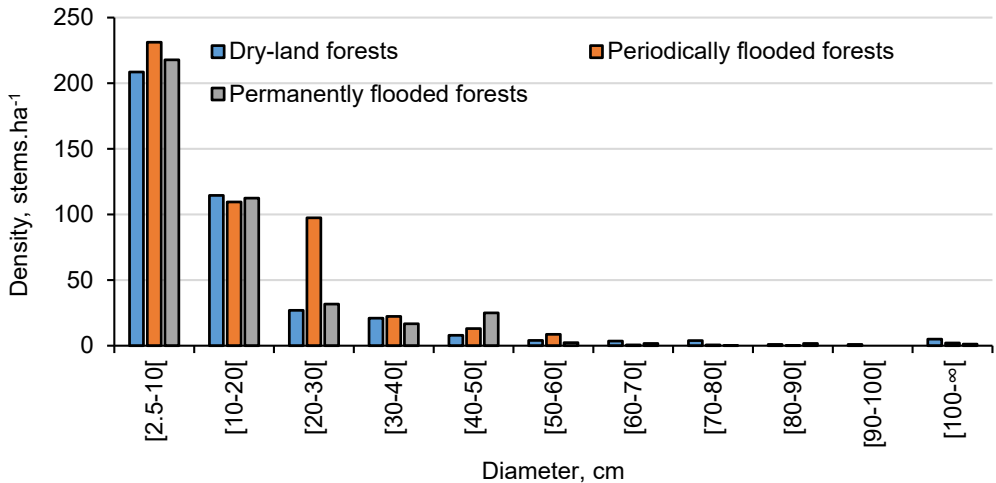


Fig. 6. Histograms of stem distribution by diameter class in different habitat types.

Relationships between species richness, diversity, density and biomass

The Principal Component Analysis (PCA) revealed the ordination between the sampled forests (Fig. 7). The plots of permanently flooded forests are the least rich, the least diverse and have the lowest biomass values. Conversely, the plots from dry-land forests are richer, more diverse and have the highest biomass values. The periodically flooded forest plots have an intermediate ordination to the other two forest types. These results confirmed the previous findings.

The diversity expressed by the Shannon index is significantly influenced by the richness of the three forest types: r -value between 1 and 8 depending on the forest and p -value < 0.05 . This means that rich-

ness is the key component of diversity in the studied forests, which explains why Shannon's entropy is correlated with it.

The other two parameters (evenness and density) do not depict a clear ordination of the plots from the three forest types. These two parameters are not related according to the Pearson correlation. On the other hand, species evenness is negatively correlated with richness in permanently flooded forests ($r = -0.452$; $p < 0.05$). Referring to Marcon (2025), this result could probably be due to a sampling effect in this forest type. However, according to Wilsey and Stirling (2007), species evenness and richness respond differently to habitat conditions. These authors suggest that evenness and richness may be influenced by different processes, with richness more influenced by the number of species in a given area and evenness

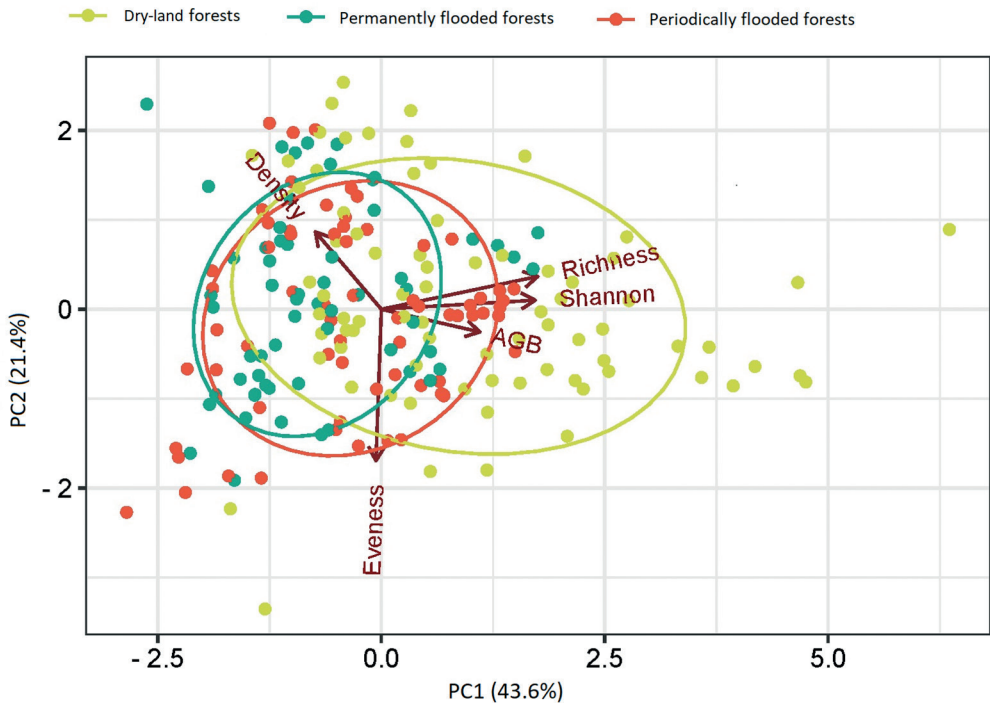


Fig. 7. Plots ordination based on floristic parameters, density and biomass.

more influenced by species interactions, such as competition. However, this last observation remains purely experimental and may not necessarily reflect the reality of permanently flooded forests.

The AGB is correlated with density for dry-land forests ($r = 0.447$ and $p < 0.05$), but this parameter remains insensitive to the other parameters. It has been shown that the lack of correlation between biomass and richness in natural ecosystems indicates that these ecosystems have reached species saturation (Cardinale et al. 2011). In the case of this study, such species saturation is likely in permanently or periodically flooded forests. Such results were also reported by Sullivan et al. (2017), who find no relationship between biomass and diversity in tropical forests. On the other hand, this result contradicts the positive association between diversity and biomass observed by Liang et al. (2016).

Conclusions and Recommendations

The results of this study have important benefits for the conservation of rural forests that are not protected by legal status. On one hand, it establishes a baseline of ecological attributes and characteristics, such as species richness and composition, biomass and rarity of woody species that make up the plant community. On the other hand, the study suggests that the abundance of *A. cordifolia* reflects a high level of degradation of these areas. Better management of this species could therefore promote the conservation value of these neglected and dispersed habitats in agrosystems.

In Côte d'Ivoire, there has been a significant increase in the development of voluntary community conservation programmes, with an emphasis on the crea-

tion of voluntary nature reserves and the protection of sacred forests. The case of the studied forest fragments is particularly interesting because these forests are home to large populations of rare, threatened and/or endemic species. These forests, therefore, deserve to be inventoried and included in processes that promote biodiversity conservation. These are initiatives being promoted by the government of Côte d'Ivoire in collaboration with local communities. However, further studies of these forests are needed to assess their extent, raise community awareness of their importance and develop simple management plans.

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