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# Mapping and Floristic Diversity of the Nakpadjouak Community Forest, Tami Canton, Togo (West Africa)

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## Abstract

Since 2015, community forests have been promoted in Togo as an alternative to protect areas from degradation and as a means of contributing to forest landscape restoration. The study focuses on the *Nakpadjouak* Community Forest (NCF) in Tami (Togo, West Africa) which contributes to community forests sustainable management. It aims in (i) mapping forest ecosystems and analysing their dynamic and (ii) characterizing the floristic diversity of the NCF. The ecosystems were mapped and their dynamic was evaluated based on Google Earth images of 2014 and 2020. Floristic and forestry inventories were carried out using the transect technique in a sample of 20 plots of 50 m × 20 m. The NCF was made up mainly by wooded/shrub savannahs (95.37%) and croplands/fallow (4.63%) in 2014. These two land use types undergone changes over the 6 years prior to 2020. By 2020, the NCF had 3 land use types: wooded/shrub savannahs (77.59%), open forest/wooded savannahs (22.23%), and croplands/fallows (0.18%). A total of 89 plant species belonging to 70 genera and 28 families were recorded within the NCF. The dominant species are: *Heteropogon contortus* (L.) P.Beauv. and *Combretum collinum* Fresen. followed by *Pteleopsissuberosa* Engl. & Diels, *Annona senegalensis* Pers. The most common species are: *Lannea acida* A.Rich. s.l., *A. senegalensis*, *Vitellaria paradoxa* C.F.Gaertner subsp. *paradoxa*, *C. collinum* and *Acacia dudgeonii* Craib ex Holland. Due to its small area of just 40 hectares and its diverse plant life, this community forest of Savannahs Region is a significant biodiversity hotspot and warrants conservation efforts.

## Keywords

Community Forest, Floristic Diversity, Land Use Change, Biodiversity Hotspot, Tami, Savannah Region, Togo

## 1. Introduction

Protected areas, both state-owned and traditional, are essential for the conservation of biodiversity and ecosystems [1]-[6]. In addition to these two most important aspects, protected areas provide a range of other ecosystem services. These include mitigating the effects of climate change, providing timber and non-timber forest products, and generating income for communities, especially in rural areas [7] [8] [9]. Nowadays, many protected areas, especially those owned by the state, are undergoing a process of anthropisation [10] [11] [12]. This relates to how they are established and managed [12]. As a result of socio-cultural upheaval, the resources of traditional protected areas, including forests and sacred groves, have also deteriorated [3] [13] [14]. In the face of the degradation of state-owned protected areas, there is a growing trend towards the establishment and management of community forests [15]. These are forests that are managed by local people. This form of management is beginning to have a greater impact on conserving forest ecosystem goods and services [16] [17]. □

Sacred and/or community forests have played a significant role in the socio-cultural live of local communities, assisting in the preservation of biodiversity especially in areas where vegetation has significantly degraded or reduced [3] [4] [14]. In Western cultures, the focus on forests has largely shifted towards recreation [18] [19] [20]. However, traditional societies across the Global South, including Latin America, Asia, Africa, and Oceania, maintain strong cultural connections between communities and specific forests. Initially, these ecosystems serve as sanctuaries for deities, spirits, or ancestors of a community [14] [21].

In addition to the socio-cultural significance, these forests serve as a significant hotspot of local biodiversity, providing an insight into the floristic history and primary vegetation of the region. The conservation of biodiversity through sacred and community forests has become a matter of growing international concern in Africa and other parts of the world [15] [16] [22]. In the Savannah

Region of Northern Togo, where forest cover, namely the protected areas are remarkably degraded [11] [23] [24] [25], sacred and community forests serve as true sanctuaries for species that have either already disappeared or are in danger of extinction. These small woodlands, ranging from a few acres to several dozen hectares, are dispersed throughout a degraded landscape and remain natural habitats for specific plant and animal species that are threatened. Apart from protecting the biodiversity and cultural significance, community forests also contribute to conserving forest landscape and increasing community resilience against climate change [16]. They also serve as a means economic revenues for residents [26] [27].

This study was carried out on the Nakpadjouak Community Forest (NCF) as part of the sustainable management of community forests in Togo. Its aims at: (i) analysing the dynamics of the forest's ecosystem from the time of its installation (2015) until today, (ii) assessing the diversity of plant species, and (iii) characterizing the demographic structure of woody plants in NCF.

## 2. Materials and Methods

### 2.1. Study Area

The studied forest, Nakpadjouak Community Forest (NCF) is located in the canton of Tami, prefecture of Tone in Savannahs' region of Togo (**Figure 1**). The NCF is a part of the ecological zone I of Togo [28] characterized by Soudanian

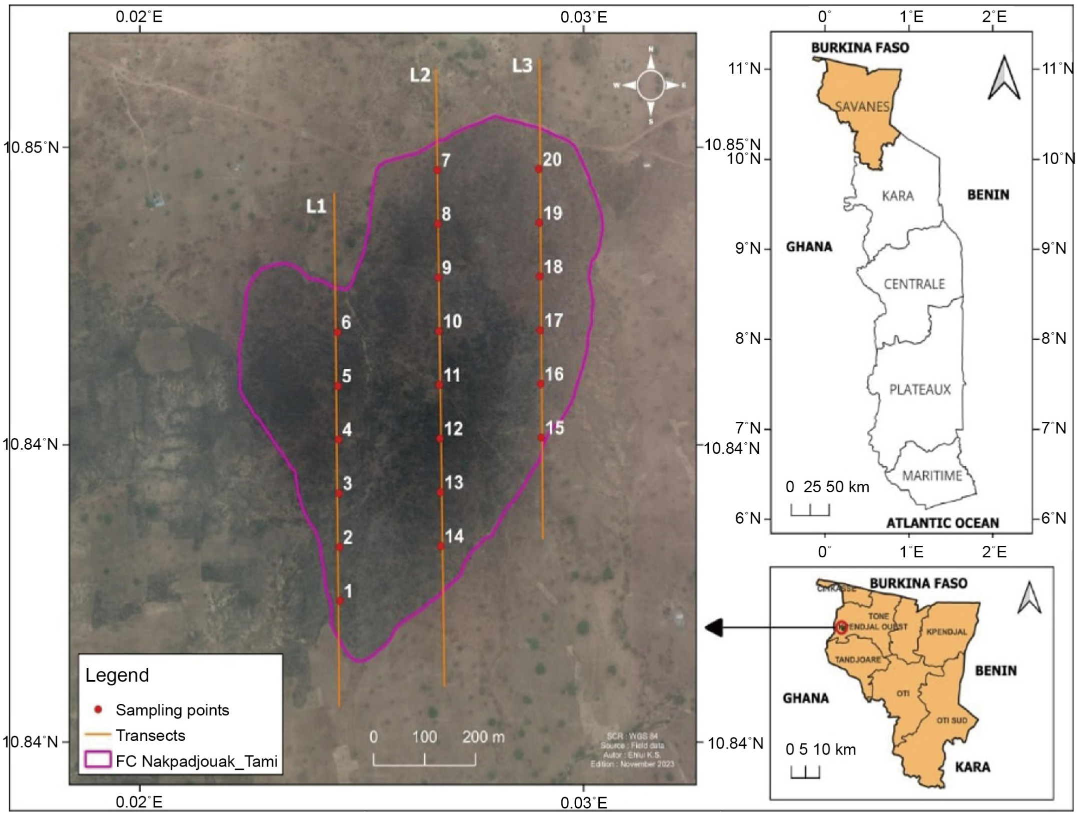


**Figure 1.** Location and sampling design of the Nakpadjouak Community Forest of in Togo, West Africa.

Savannahs stands [29]. Due to the soaring popularization, the native ecosystems were transformed to croplands and agroforestry parklands [30].

## 2.2. Data Collection

### 2.2.1. Sattelite Image Acquisition

The NCF map did not exist before this study. Therefore, the first activity was to demarcate the NCF. The mobile application LocustMap was used to record the routes and geographical coordinates. To digitise the land use units, the recorded route and GPS (Global Positioning System) coordinates were projected in Google Earth Pro software. Google Earth images provided by Astrium Service to Google Inc. in 2021 were used to map the land use units. The choice of these images was due to their high resolution (up to 1.5 m) and the small area of the NCF [11] [31].

### 2.2.2. Sampling Design

Field data were collected along three transects 200 m apart. For the inventories, 100 m equidistant sampling points were established along each transect. This sampling method produced a total of 20 throughout the NCF. For phytosociological inventories of woody species, ecological inventories and forest inventories, the plot size was 50 m × 20 m [32]. Phytosociological surveys of herbaceous flora were executed within plots of 10 m × 10 m [33]. Three diagonally arranged 5 m × 5 m sub-plots, one (1) in the centre and the other two (2) in the opposite corners on either side of the central plot, were defined within each large 50 m × 20 m plot for the regeneration inventory [33] [34] [35].

### 2.2.3. Phytosociological and Forest Inventories

Phytosociology surveys were conducted using a standard phytosociology form with following information: plot code, survey date, locality, geographical coordinates of point and type of surface survey. All species (woody and herbaceous) present in the defined inventory areas were listed. They were assigned an abundance/dominance coefficient according to Braun-Blanquet [36]. This scale is defined as follows: +: rare species, cover 0 to 1%; 1 = cover 1 to 5%; 2 = cover 5 to 25%; 3 = cover 25 to 50%; 4 = cover 50 to 75%; 5 = cover 75 to 100%.

Tree diameter, stem height and total height of woody plants with DBH ≥ 5 cm were measured during the forest inventory. Tree diameter was measured at 1.30 m from the ground using a forestry compass. Visual scoring was used to assess the height of the trunk and total height. Crown diameter was assessed in north-south and east-west directions. Potential regeneration was defined as all woody species with a DBH < 5 cm [37].

## 2.3. Data Analysis

### 2.3.1. Land Use Unit Mapping

The different land-use units were digitised using Google Earth Pro software while QGIS software was used to create the maps [31] [32]. The coordinates of the points of the different formations were recorded in the field using GPS.

These were projected onto the Google Earth image to validate the maps previously produced. After digitisation, the layers generated were saved in KML format. They were then projected onto a background map of Togo, WGS 84_UTM Zone 31N, using QGIS 2.18.

#### 2.3.2. Assessment of the Floristic Diversity

Microsoft Excel spreadsheets were used to record the data collected in the field. The analysis consisted of compiling a list of the species found. These were then grouped by family and genus. The classification used is that of APG IV [22]. It can be consulted on the website https://africanplantdatabase.ch/en. The biological and phytogeographical types of these species are identified in the following reference documents [38] [39]. Phanerophytes (Ph), chamephytes (Ch), hemicryptophytes (He), geophytes (Ge), therophytes (Th) and epiphytes are the categories of biological types considered. Phanerophytes include: megaphanerophytes (MP) (trees over 30 m), mesophanerophytes (mP) (trees 10 to 30 m), microphanerophytes (mp, trees 2 to 10 m), nanophanerophytes (np, trees 0.4 to 2 m), lianaceous forms (Lnp, Lmp, LmP, LMP) [23].

#### 2.3.3. Forest Characteristics Analysis

Dendrometry parameters such as trees density per hectare (D), mean Lorey height (HL in m), mean diameter (Dm in cm) and basal area (G in $m^2$/ha) were calculated [40]. Tree density (N) is assessed as the number of trees per hectare according to the following formula N = n/s where "n" is the number of trees of DBH ≥ 5 cm on the plot and "s" is the area of the plot in hectares. Basal area (G, $m^2$/ha) is the sum of the cross-sections at 1.30 m above the ground of all trees in a plot. It is converted into hectares. It is calculated according to the formula G = Σπd2/4s, where d is the diameter and s is the area of the group. Mean Lorey Height is calculated by averaging tree heights weighted by basal area [41].

The trees are grouped into 10 cm diameter classes and 2 m height classes. Minimum diameter and height are 5 cm and 2 m respectively. The 3 Weibull parameters (a = location parameter, b = scale or size parameter and c = shape parameter related to the diameter or height structure) were used to fit the demographic structures of trees to the theoretical distribution [37].

## 3. Results

### 3.1. Land Use Units Dynamic

*Nakpadjouak* community forest consisted of two types of land use types in 2014 (**Figure 2**). Wooded/shrub savannahs is the most common (95.37%). It is followed by croplands/fallows (4.63%). Three types of land use have been identified in 2020. These are wooded/shrub savannahs (77.59%), open forests/wooded savannahs (22.23%) and croplands/fallows (0.18%).

From 2014 to 2020, the *Nakpadjouak* community forest was characterised by the emergence of open forests/wooded savannahs. The wooded/shrub savannah and the fields/fallows decreased by −17.80% and −4.44% respectively (**Table 1**).

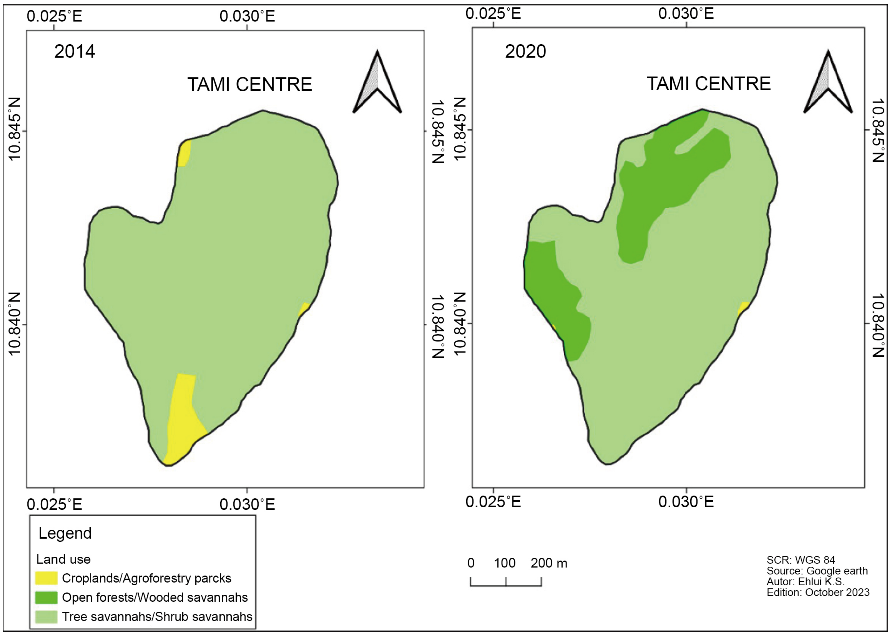


**Figure 2.** Land use in *Nakpadjouak* community forest in 2014 and 2020.

**Table 1.** Change rate of land use of NCF from 2014 to 2020.

| Land use | 2014 | | 2020 | | Change rate |
|---|---|---|---|---|---|
| | **Area (ha)** | **%** | **Area (ha)** | **%** | **2014-2020** |
| Croplands/Fallows | 2.03 | 4.63 | 0.08 | 0.18 | −4.44 |
| Open forests/Tree savannahs | 0.00 | 0.00 | 9.75 | 22.23 | 100 |
| Wooded/Shrubs savannahs | 41.84 | 95.37 | 34.03 | 77.59 | −17.80 |
| Total | 43.87 | 100 | 43.86 | 100 | |

The main conversions that took place between 2014 and 2020 are identified by analysing the land use transition matrix for the NCF (**Figure 3**). According to this analysis, 22.22% of wooded savannah/shrubland converted to open forest/wooded savannah and 4.49% of cropland to wooded savannah/shrubland (**Table 2**).

## 3.2. Floristic Diversity of NCF

There are 89 species of plants that have been recorded in the Nakpadjouak community forest (**Appendix**). These belong to 70 genera and 28 families. The dominant species are: *Heteropogon contortus* (L.) P.Beauv. and *Combretum collinum* Fresen., followed by *Pteleopsis suberosa* Engl. & Diels, *Annona senegalensis* Pers. (**Figure 4**). The most frequent species are: *Lannea acida* A.Rich. s.l., *A. senegalensis*, *Vitellaria paradoxa* C.F.Gaertner subsp. *paradoxa*, *C. collinum* and *Acacia dudgeonii* Craib ex Holland.

Fabaceae with 23 species is the most important family. This is followed by Combretaceae (8 species), Rubiaceae (8 species), Poaceae (6 species) and Malvaceae (5 species). Combretaceae, Poaceae and Fabaceae are the most dominant

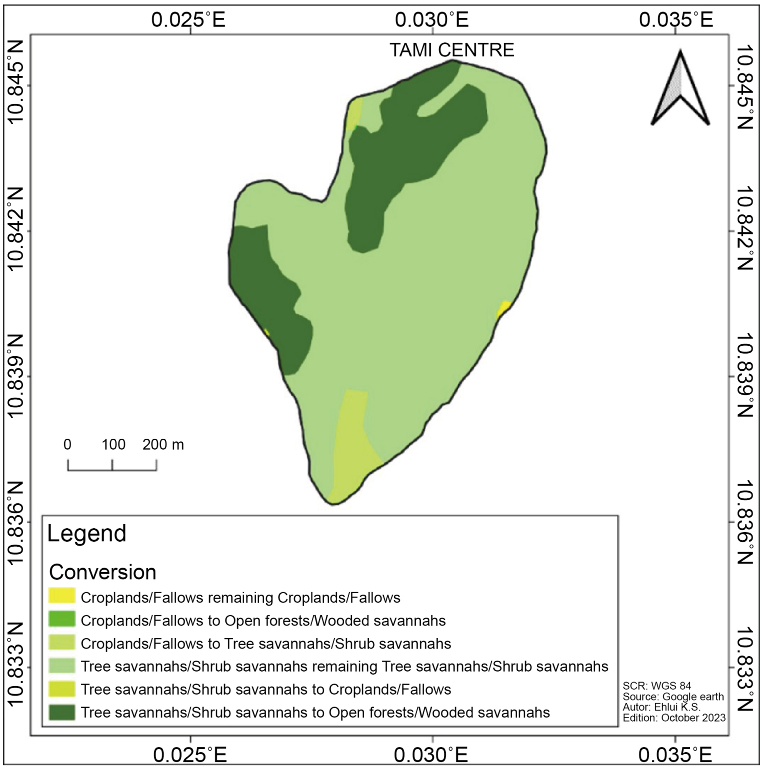


**Figure 3.** Change of land use in NCF.

**Table 2.** Land use transition matrix 2014-2020.

| | | 2020 | | | |
|---|---|---|---|---|---|
| | | C/F | OF/WS | TS/SS | Total |
| 2014 | **C/F** | **0.14** | 0 | 4.49 | 4.63 |
| | **TS/SS** | 0.05 | 22.22 | **73.1** | 95.37 |
| | **Total** | 0.18 | 22.22 | 77.59 | 100 |

C/F: Croplands/Fallows, OF/WS: Open forests/Wooded savannahs, TS/SS: Tree/Shrub savannahs.

families based on the weighted spectrum (**Figure 5**).

Within the NCF, four phytogeographical plant types are represented. Transitional species (GC-SZ, 61.89%) were the most common. They were followed by the Soudano-Zambezian species (SZ, 36.68%). Guineo-Congolese forest and introduced species were rarely present (**Figure 6**). Looking at the raw spectrum based on the number of species per biological type, the trend is the same: 51.81%, 39.33%, 5.62 and 2.25% respectively.

The weighted as raw spectrum showed that the most represented biological types in the NCF are the microphanerophytes and the nanophanerophytes (**Figure 7**). The therophytes are more diversified than the hemicryptophytes. However, they are less abundant than the latter. The other biological types of plants are less abundant and less diversified in the NCF than the hemicryptophytes.

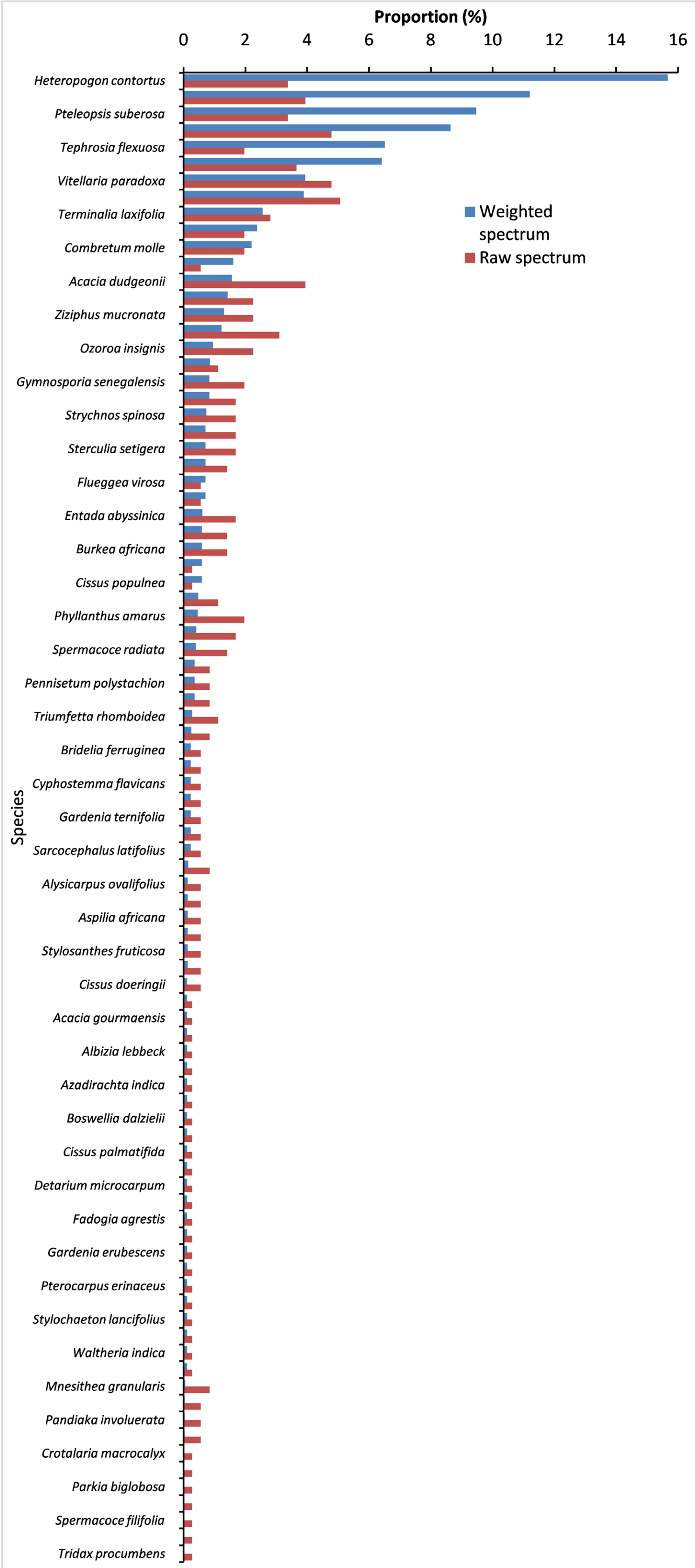


**Figure 4.** Weighted and raw spectrums of the plant species in the NCF.

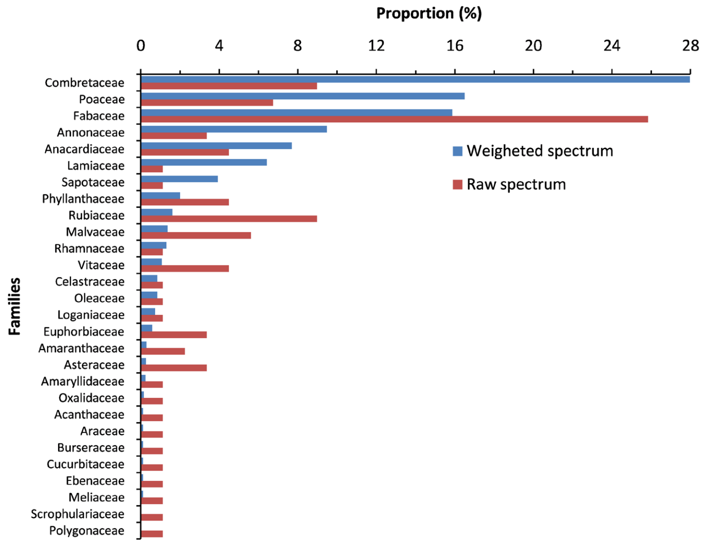


**Figure 5.** Weighted and raw spectrums of families in the NCF.

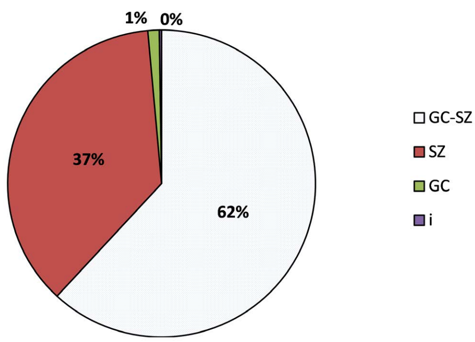


**Figure 6.** Weighted phytogeographical spectrum of plant species in the NCF. GC = Guineo-Congolese, SZ = Soudano-Zambezian, GC-SZ = Guineo-Congolese/Soudano-Zambezian, I = Introduced.

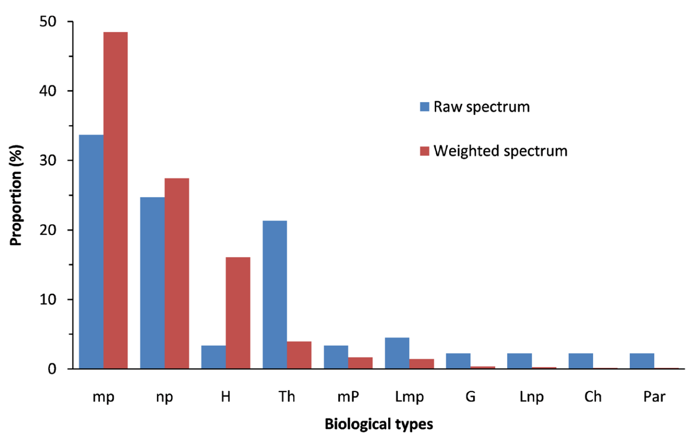


**Figure 7.** Weighted and raw spectrums of plant biological types in the NCF. Ch = chamephyte, G = geophyte, H = hemicryptophyte, Lmp = liana mesophanerophyte, Lnp = liana microphanerophyte, np = nanophanerophyte, mp = microphanerophyte, mP = mesophanerophyte, Par = Parasit, Th = therophyte.

The NCF floras included one endangered species (*Vitellaria paradoxa*) and one threatened species (*Pterocarpus erinaceus*). The IUCN Red List criteria do not apply to almost half of the species (48.31%). A proportion of 43.82% of plants are of low concern.

### 3.3. Description of Plant Communities

Three plants communities were discriminated in NCF based on the hierarchical ascendant classification (HAC) at 1.3 of Euclidian distance (**Figure 8**). These are: the plant community of *Lannea acida* and *Combretum collinum* (G1), the plant community of *Vitellaria paradoxa* and *Acacia dodgoenii* (G2), and the plant community of *Vitellaria paraxa* and *Lannea acida* (G3).

G1 of 5 wooded savannah plots is dominated by *Lannea acida* and *Combretum collinum* with IVI 147.15 and 127.28. These are followed by *Terminalia avicennioides*, *Acacia dudgeonii* and *Combretum molle*. A total of 18 species of woody plants were recorded. They belong to 10 families. Anacardiaceae (FIV = 82.80) and Combretaceae (71.67) are the most important families. The family with the greatest diversity is the Fabaceae, with 5 species (**Table 3**). The mean density was 276 stems/ha with a basal area of 3.61 $m^2$/ha. The mean height (7.32 m) and mean diameter (12.91 cm) were the lowest.

G2 included 15 woody plant species recorded in 9 plots of shrub/wood savannahs. With IVI 127.38 and 107.42 respectively, *Vitellaria paradoxa* and *Acacia dudgeonii* dominated. Then came *Lannea acida*. The 15 species are distributed in 6 families. Combretaceae is the most diverse (6 species) and important (FIV, 93.59) family. It is followed by the Fabaceae (FIV, 88.97). The tree density corresponds to 136 stems/ha with 4.00 $m^2$/ha. The average total height and diameter are 8.45 m and 19.39 cm respectively.

There are 6 tree savannah plots in G3. Eight species of woody plants belong to four families in the census. *Vitellaria paradoxa and Lannea acida* are the

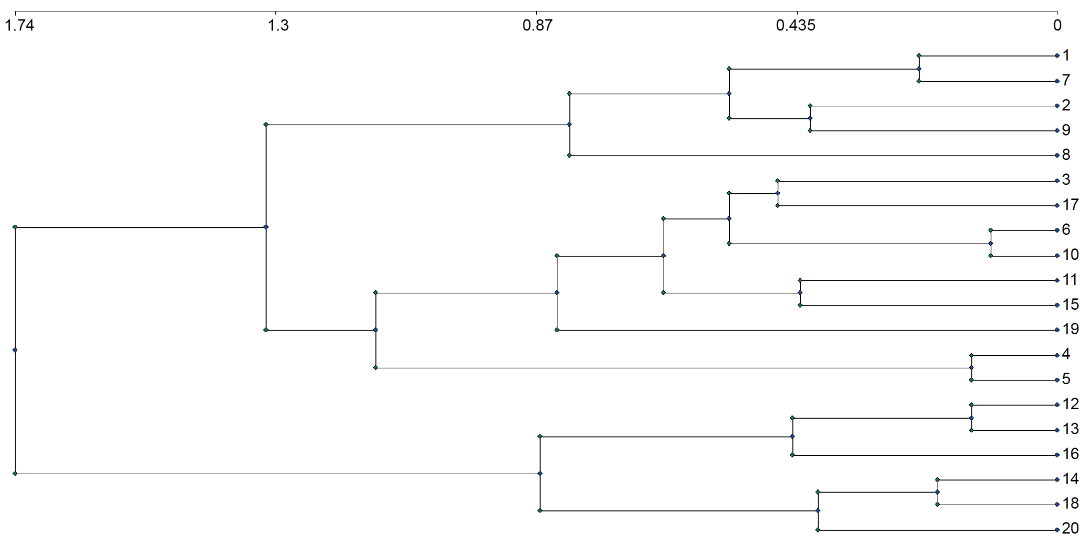


**Figure 8.** Discrimination of plots according to Hierachical Ascendant Classification (HAC).

**Table 3.** Importance Value Indices (IVI) of woody species within each plant community.

(a)

| Groups | Scientific name | DENR | DOM | FR | IVI |
|---|---|---|---|---|---|
| G1 | *Lannea acida* A.Rich. s.l. | 22.46 | 24.69 | 100.00 | 147.15 |
| | *Combretum collinum* Fresen. | 15.94 | 11.33 | 100.00 | 127.28 |
| | *Terminalia avicennioides* Guill. ex Perr. | 10.14 | 3.84 | 80.00 | 93.98 |
| | *Acacia dudgeonii* Craib ex Holland | 13.04 | 10.98 | 60.00 | 84.03 |
| | *Combretum molle* R.Br. ex G.Don | 8.70 | 5.05 | 60.00 | 73.74 |
| | *Lannea microcarpa* Engl. & K. Krause | 2.90 | 6.28 | 60.00 | 69.17 |
| | *Vitellaria paradoxa* C.F.Gaertner subsp. *paradoxa* | 6.52 | 9.32 | 40.00 | 55.84 |
| | *Sclerocarya birrea* (A.Rich.) Hochst. | 5.07 | 4.73 | 40.00 | 49.80 |
| | *Burkea africana* Hook. | 5.07 | 4.70 | 40.00 | 49.77 |
| | *Boswellia dalzielii* Hutch. | 1.45 | 4.19 | 40.00 | 45.64 |
| | *Sterculia setigera* Delile | 1.45 | 10.19 | 20.00 | 31.64 |
| | *Entada abyssinica* Steud. ex A.Rich. | 1.45 | 1.71 | 20.00 | 23.16 |
| | *Hexalobus monopetalus* (A.Rich.) Engl. & Diels | 1.45 | 1.53 | 20.00 | 22.98 |
| | *Strychnos spinosa* Lam. | 1.45 | 0.37 | 20.00 | 21.82 |
| | *Prosopis africana* (Guill. & Perr.) Taub. | 0.72 | 0.53 | 20.00 | 21.25 |
| | *Acacia nilotica* (L.) Willd. subsp. *astringens* (Schum. & Thonn.) Rob. | 0.72 | 0.28 | 20.00 | 21.00 |
| | *Bridelia scleroneura* Müll.Arg. | 0.72 | 0.21 | 20.00 | 20.94 |
| | *Azadirachta indica* A.Juss. | 0.72 | 0.07 | 20.00 | 20.79 |
| G2 | *Vitellaria paradoxa* C.F.Gaertner subsp. *paradoxa* | 18.03 | 20.46 | 88.89 | 127.38 |
| | *Acacia dudgeonii* Craib ex Holland | 20.49 | 9.15 | 77.78 | 107.42 |
| | *Lannea acida* A.Rich. s.l. | 11.48 | 8.59 | 66.67 | 86.73 |
| | *Combretum molle* R.Br. ex G.Don | 7.38 | 2.77 | 55.56 | 65.70 |
| | *Terminalia mollis* M.A.Lawson | 10.66 | 13.34 | 33.33 | 57.33 |
| | *Burkea africana* Hook. | 7.38 | 2.29 | 44.44 | 54.12 |
| | *Prosopis africana* (Guill. & Perr.) Taub. | 0.82 | 28.83 | 11.11 | 40.77 |
| | *Sterculia setigera* Delile | 2.46 | 4.84 | 33.33 | 40.63 |
| | *Anogeissus leiocarpa* (DC.) Guill. & Perr. | 9.84 | 3.34 | 22.22 | 35.39 |
| | *Lannea microcarpa* Engl. & K. Krause | 2.46 | 3.38 | 22.22 | 28.06 |
| | *Terminalia laxifolia* Engl. | 3.28 | 0.67 | 22.22 | 26.17 |
| | *Lannea microcarpa* Engl. & K. Krause | 1.64 | 1.26 | 11.11 | 14.01 |
| | *Strychnos spinosa* Lam. | 2.46 | 0.39 | 11.11 | 13.96 |
| | *Combretum collinum* Fresen. | 0.82 | 0.43 | 11.11 | 12.36 |
| | *Terminalia avicennioides* Guill. ex Perr. | 0.82 | 0.26 | 11.11 | 12.19 |

**Continued**

| | | | | | |
|---|---|---|---|---|---|
| G3 | *Vitellaria paradoxa* C.F.Gaertner subsp. *paradoxa* | 44.07 | 46.98 | 83.33 | 174.38 |
| | *Lannea acida* A.Rich. s.l. | 25.42 | 29.10 | 100.00 | 154.53 |
| | *Entada abyssinica* Steud. ex A.Rich. | 10.17 | 8.53 | 50.00 | 68.70 |
| | *Lannea microcarpa* Engl. & K. Krause | 8.47 | 11.03 | 33.33 | 52.84 |
| | *Pterocarpus erinaceus* Poir. | 3.39 | 1.21 | 16.67 | 21.27 |
| | *Anogeissus leiocarpa* (DC.) Guill. & Perr. | 3.39 | 0.62 | 16.67 | 20.68 |
| | *Acacia dudgeonii* Craib ex Holland | 3.39 | 0.52 | 16.67 | 20.58 |
| | *Terminalia avicennioides* Guill. ex Perr. | 1.69 | 2.00 | 16.67 | 20.37 |

(b)

| Groups | Families | DENR | DOM | DIV | FIV |
|---|---|---|---|---|---|
| G1 | Anacardiaceae | 30.43 | 35.69 | 16.67 | 82.80 |
| | Combretaceae | 34.78 | 20.22 | 16.67 | 71.67 |
| | Fabaceae | 21.01 | 18.20 | 27.78 | 66.99 |
| | Sapotaceae | 6.52 | 9.32 | 5.56 | 21.40 |
| | Sterculiaceae | 1.45 | 10.19 | 5.56 | 17.19 |
| | Burseraceae | 1.45 | 4.19 | 5.56 | 11.20 |
| | Annonaceae | 1.45 | 1.53 | 5.56 | 8.54 |
| | Loganiaceae | 1.45 | 0.37 | 5.56 | 7.37 |
| | Phyllanthaceae | 0.72 | 0.21 | 5.56 | 6.49 |
| | Meliaceae | 0.72 | 0.07 | 5.56 | 6.35 |
| G2 | Combretaceae | 32.79 | 20.81 | 40.00 | 93.59 |
| | Fabaceae | 28.69 | 40.28 | 20.00 | 88.97 |
| | Anacardiaceae | 15.57 | 13.22 | 20.00 | 48.80 |
| | Sapotaceae | 18.03 | 20.46 | 6.67 | 45.16 |
| | Sterculiaceae | 2.46 | 4.84 | 6.67 | 13.96 |
| | Loganiaceae | 2.46 | 0.39 | 6.67 | 9.52 |
| G3 | Sapotaceae | 44.07 | 46.98 | 25.00 | 116.05 |
| | Anacardiaceae | 33.90 | 40.14 | 25.00 | 99.03 |
| | Fabaceae | 16.95 | 10.26 | 37.50 | 64.71 |
| | Combretaceae | 5.08 | 2.62 | 12.50 | 20.21 |

most important. Their IVI is 174.38 and 154.53 respectively. Sapotaceae (116.01) and Anacardiaceae (99.03) are the most important families. The density is 98 stems/ha. The basal area is 4.08 $m^2$/ha. This group has the highest mean total height (9.03 m) and mean diameter (22.99 cm).

## 3.4. Demographic Structure

The distribution of trees by diameter class of G1 and G3 has a reversed J-shape, where c < 1 (see **Figure 9**). The distribution is positively asymmetric for G3.

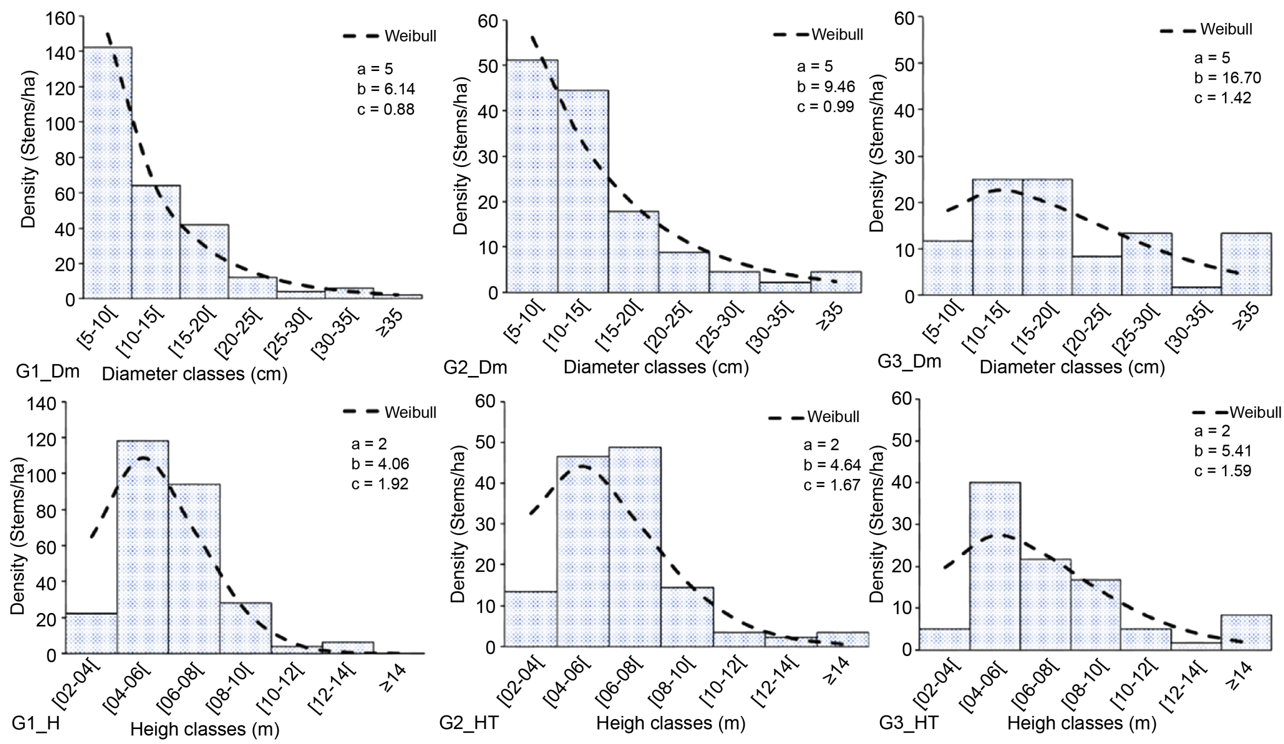


**Figure 9.** Nakpadjouak community forest plant community diameter and height structure.

Young trees are most dominant in these groups. The height distribution of individuals within clusters shows positive asymmetry. The theoretical shape coefficient of the Weibull distribution is between 1 and 3.6. Trees with low height are more represented in this structure.

## 4. Discussion

### 4.1. Land Use Change

Analysis of Google Earth images of the Nakpadjouak community forest shows a progressive vegetation dynamic between 2014 and 2020. A regression of tree savannah/shrub savannah and fields/fallow land was observed. Tree savannas/shrub savannas have mostly regressed in favour of the open forest/wooded savannah class. Fields and fallows, on the other hand, regressed in favour of wooded savannah/shrub savannah. This result is similar to that of Egbelou *et al.* [31]. He noted a progression of vegetation formations at the expense of fields in the Aboudjokopé forest over the period 2012-2018. The same observation was made by Kombate, B *et al.* (2023) in the Alibi I community forest. [16] The appearance of the open forest/forested savannah class in 2020 is due to the conservation measures implemented by the community. These measures have allowed certain parts of the savannah formation to grow and give rise to open forest/wooded savannah. These measures have also allowed certain parts of the fields to be converted to wooded savannah/shrub savannah [32]. The result obtained in this study differs from that of Koumoi *et al.* (2013). They found a regression of vegetation formations in favour of anthropogenic formations. Polo-Akpisso *et al.* (2015) [33] also found the same result as Koumoi *et al.* [42] in the Oti-Keran-Mandouri National Park.

### 4.2. Floristic Diversity

The survey of plant life conducted in Nakpadjouak community forest identified a variety of 89 species, classified into 70 genera and 29 families. Similarly, a comparable survey was carried out in a community forest located in the Dankpen prefecture, situated southwards in the same ecological region, yielding 84 species [32]. The floricule of the NCF is comparatively lower than that of other community forests situated in Togo's different ecological zones that receive higher amounts of rainfall. In these areas, the NCF's floricule is only slightly more than double. The Afem-Boussou and Alibi 1 community forests in this ecological zone have a diversity of 163 and 229, respectively [22] [30]. In ecological zone 4, the floral diversity is lower than what was found by Egbelou *et al.* [31]. Atakpama *et al.* (2018) recorded diversity of 109, 188, 217 and 264 in the community forests of Edouwossi-Copé, Agbedougbé, Aboudjokopé and Amavénou respectively [26] [27] [31]. In addition to the more advantageous conditions found in other ecological zones, the size of the forest and the lack of watercourses in the NCF contribute to limited floristic diversity.

The dominance of Combretaceae followed by Poaceae and Fabaceae characterizes the flora of Nakpadjouak community forest. This tendency points to generally dry climatic conditions in this area [27] [43] [44]. The prevalence of these families is also documented in numerous studies of the region [3] [44]. The prevalence of the Combretaceae family may be attributed to its natural regeneration ability through seedlings, suckering and/or stump sprouting [45]. Additionally, its abundance highlights the susceptibility of this community forest's ecosystems to wildfire [44].

Four biological types were observed, with microphanerophytes being the most common. This prevalence of microphanerophytes has also been recognized by various authors in the same area [23] [46]. The dominance of microphanerophytes indicates the savannah nature of the vegetation.

Based on phytogeographic type, the most prominently featured species are the Guineo-Congolese/Sudano-Zambézian transition species (61.89%) and Sudano-Zambézian species (36.68%). This finding aligns with Atakpama *et al.* (2021) results and with Dimobe *et al.*'s (2012) [3] [23] observation of Sudano-Zambezian species' dominance in the Oti-Mandouri wildlife reserve.

### 4.3. Demographic Structure

The horizontal structure in groups G1 and G2 shows an "inverted J" diametric distribution. This result is comparable to that of Kombate *et al.* (2023) [47]. This structure reflects the presence of strong anthropogenic pressure in both groups. It also suggests the presence of several future stems to ensure forest reconstitution [48]. On the other hand, the diametric structure in group G3 shows a positive asymmetric distribution, with a predominance of individuals with diameters between 10 and 20m. This distribution is characteristic of stands with a predominance of small diameter individuals [49].

The distribution is positively asymmetric, with a predominance of individuals between 4 and 6 m tall in groups G1 and G3, and a predominance of individuals between 6 and 8 m tall in group G2. This distribution reflects a strong representation of young, short individuals. This result is similar to that of Kombate, Bimare *et al*. [47].

## 5. Conclusion

Spatio-temporal dynamics indicate forest recovery in the Nakpadjouak community forest. A total of 89 plant species, belonging to 70 genera and 29 families, were identified (**Appendix**). *Heteropogon contortus* (L.) P.Beauv. and *Combretum collinum* Fresen, followed by *Pteleopsis suberosa* Engl. & Diels, *Annona senegalensis* Pers are the dominant species. Dominant families are Combretaceae, Poaceae and Fabaceae. Nakpadjouak community forest is also home to one endangered (*Vitellaria paradoxa*) and one threatened (*Pterocarpus erinaceus*) species. Forest demographic structures indicate a predominance of small-diameter and low-height trees. Protection against pasture use, wood removal and wildfire management are pivotal to forest land sustainability. The promotion of revenue-generating activities will help to the restoration of the forest to its optimal state. The Nakpadjouak community forest is currently undergoing full restoration due to its community management and the support of NGOs. Future studies could assess its carbon storage potential, contribution to mitigating climate change, and ecosystem services provided to the local community.

## Author Contributions

Conceptualization, K.S.E.; methodology, K. S. E., W. A., A. B.; software, K.S.E., W. A.; validation, W.A., E.K., C.A-K.Y. and HvW.; formal analysis, K.S.E., W.A; investigation, K.S.E, W.A.; resources, K.S.E; data curation, K.S.E., W.A.; writing—original draft preparation, K.S.E.; writing—review and editing, K.S.E., HvW, W.A., C.A-K., E.K.; visualization, K.S.E.; supervision, C.A-K, K.E. and H.vW; project administration, K.S.E.; funding acquisition, K.S.E. All authors have read and agreed to the published version of the manuscript.

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## Data Availability Statement

WASCAL data is open access and will be made available when a formal request is received by the institution through the Data Administration Unit.


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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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## Appendix: List of Plant Species within Nakpadjouak Community Forest (NCF)

| Species | Families | Biological types | Phytogeography |
|---|---|---|---|
| *Abutilon mauritianum* (Jacq.) Medik. | Malvaceae | np | GC-SZ |
| *Acacia dudgeonii* Craib ex Holland | Fabaceae | mp | SZ |
| *Acacia gourmaensis* A.Chev. | Fabaceae | mp | SZ |
| *Acacia nilotica* (L.) Willd. subsp. *astringen*s (Schum. & Thonn.) Rob. | Fabaceae | mp | SZ |
| *Acacia seyal* Delile var. seyal | Fabaceae | mp | SZ |
| *Acalypha ciliata* Forssk. | Euphorbiaceae | Th | GC |
| *Agelanthus dodoneifolius* (DC.) Polh. & Wiens | Annonaceae | Par | SZ |
| *Albizia lebbeck* (L.) Benth. | Fabaceae | mp | i |
| *Alysicarpus ovalifolius* (Schumach.) J.Léonard | Fabaceae | Th | GC-SZ |
| *Andropogon gayanus* Kunth var. *bisquamulatus* (Hochst.) Hack. | Poaceae | H | GC-SZ |
| *Annona senegalensis* Pers. | Annonaceae | np | GC-SZ |
| *Anogeissus leiocarpa* (DC.) Guill. & Perr. | Combretaceae | mP | SZ |
| *Aspilia africana* (Pers.) Adams | Asteraceae | np | SZ |
| *Asystasia gangetica* (L.) T.Anderson | Acanthaceae | np | GC-SZ |
| *Azadirachta indica* A.Juss. | Meliaceae | mp | i |
| *Bidens bipinnata* L. | Asteraceae | Th | GC-SZ |
| *Biophytum umbraculum* Welw. | Oxalidaceae | Th | GC-SZ |
| *Boswellia dalzielii* Hutch.i | Burseraceae | mP | SZ |
| *Bridelia ferruginea* Benth. | Phyllanthaceae | np | GC-SZ |
| *Bridelia scleroneura* Müll.Arg. | Phyllanthaceae | np | SZ |
| *Burkea africana* Hook. | Fabaceae | mp | SZ |
| *Chamaecrista mimosoides* (L.) Greene | Fabaceae | Th | GC-SZ |
| *Chamaecrista rotundifolia* (Pers.) Greene | Fabaceae | Th | GC-SZ |
| *Cissus palmatifida* (Baker) Planch. | Vitaceae | Lmp | SZ |
| *Cissus populnea* Guill. & Perr. | Vitaceae | Lmp | GC-SZ |
| *Combretum collinum* Fresen. | Combretaceae | mp | GC-SZ |
| *Combretum molle* R.Br. ex G.Don | Combretaceae | mp | SZ |
| *Combretum nigricans* Lepr. ex var. elliotii (Engl. & Diels) Aubrev. | Combretaceae | mp | SZ |
| *Crinum jagus* (J.Thomps.) Dandy | Amaryllidaceae | G | GC-SZ |
| *Crotalaria macrocalyx* Benth. | Fabaceae | np | SZ |
| *Crotalaria retusa* L. | Fabaceae | np | GC-SZ |
| *Cyphostemma adenocaule* (Steud.) Desc. | Vitaceae | Lmp | GC-SZ |
| *Cyphostemma flavicans* (Baker) Desc. | Vitaceae | H | GC-SZ |
| *Detarium microcarpum* Guill. & Perr. | Fabaceae | mp | SZ |
| *Dichrostachys cinerea* (L.) Wight & Am. | Fabaceae | mp | GC-SZ |
| *Diospyros mespiliformis* Hochst. ex A.DC. | Ebenaceae | mp | GC-SZ |

**Continued**

| | | | |
|---|---|---|---|
| *Entada abyssinica* Steud. ex A.Rich. | Fabaceae | Lmp | GC-SZ |
| *Euphorbia convolvuloides* Hochst. ex Benth. | Euphorbiaceae | Th | GC |
| *Fadogia agrestis* Schweinf. ex Hiern | Rubiaceae | np | SZ |
| *Flueggea virosa* (Roxb. ex Willd.) Voigt | Phyllanthaceae | np | GC-SZ |
| *Gardenia aqualla* Stapf & Hutch. | Rubiaceae | np | GC-SZ |
| *Gardenia erubescens* Stapf & Huteh. | Rubiaceae | np | GC-SZ |
| *Gardenia ternifolia* Schumaeh. & Thonn | Rubiaceae | np | GC-SZ |
| *Gymnosporia senegalensis* (Lam.) Loes. | Celastraceae | np | SZ |
| *Heteropogon contortus* (L.) P.Beauv. | Poaceae | H | GC-SZ |
| *Hexalobus monopetalus* (A.Rich.) Engl. & Diels | Annonaceae | mp | SZ |
| *Hyptis spicigera* Lam. | Lamiaceae | np | GC-SZ |
| *Lannea acida* A.Rich. s.l. | Anacardiaceae | mp | GC-SZ |
| *Lannea microcarpa* Engl. & K. Krause | Anacardiaceae | mp | SZ |
| *Loudetia hordeiformis* (Stapf) C.E.Hubbard | Poaceae | Th | GC-SZ |
| *Mnesithea granularis* (L.) Koning & Sosef | Poaceae | Th | GC-SZ |
| *Mukia maderaspatana* (L.) M.Roem. | Cucurbitaceae | Lnp | GC-SZ |
| *Ozoroa insignis* Delile | Anacardiaceae | np | SZ |
| *Pandiaka angustifolia* (Vahl) Hepper | Amaranthaceae | Th | GC-SZ |
| *Pandiaka involuerata* (Moq.) Hook.f. | Amaranthaceae | Th | GC-SZ |
| *Parkia biglobosa* (Jacq.) R.Br. ex Benth. | Fabaceae | mp | GC-SZ |
| *Pennisetum polystachion* (L.) Schult. | Poaceae | Th | GC-SZ |
| *Phyllanthus amarus* Schumach. & Thonn. | Phyllanthaceae | Th | GC |
| *Piliostigma thonningii* (Schumach.) Milne-Redh. | Fabaceae | np | GC-SZ |
| *Polygala multiflora* Poir. | Polygonaceae | Th | GC-SZ |
| *Prosopis africana* (GuilI. & Perr.) Taub. | Fabaceae | mp | SZ |
| *Pteleopsis suberosa* Engl. & Diels | Combretaceae | mp | SZ |
| *Pterocarpus erinaceus* Poir. | Fabaceae | mp | SZ |
| *Sarcocephalus latifolius* (Sm.) E.A.Bruce | Rubiaceae | mp | GC-SZ |
| *Sclerocarya birrea* (A.Rich.) Hochst. | Anacardiaceae | mp | SZ |
| *Senna obtusifolia* (L.) H.S.Irwin & Barneby | Fabaceae | np | GC-SZ |
| *Sida urens* L. | Malvaceae | np | GC |
| *Spermacoce filifolia* (Schumach. & Thonn.) J.-P.Lebrun & Stork | Rubiaceae | Th | GC-SZ |
| *Spermacoce radiata* (DC.) Hiem | Rubiaceae | Th | GC-SZ |
| *Spermacoce ruelliae* DC. | Rubiaceae | Th | GC-SZ |
| *Sterculia setigera* Delile | Malvaceae | mp | SZ |
| *Striga hermonthica* (DeliIe) Benth. | Scrophulariaceae | Par | SZ |
| *Strychnos spinosa* Lam. | Loganiaceae | mp | SZ |

**Continued**

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| *Stylochaeton lancifolius* Kotsehy & Peyr. | Araceae | G | GC-SZ |
| *Stylosanthes fruticosa* (Retz.) Alston | Fabaceae | Ch | GC-SZ |
| *Tephrosia flexuosa* G.Don | Fabaceae | np | GC-SZ |
| *Terminalia avicennioides* Guill. ex Perr. | Combretaceae | mp | SZ |
| *Terminalia laxifolia* Engl. | Combretaceae | mp | SZ |
| *Terminalia macroptera* Guill. & Perr. | Combretaceae | mp | SZ |
| *Thelepogon elegans* Roth ex Roem. & Sehult. | Poaceae | Th | SZ |
| *Tragia benthamii* Baker | Euphorbiaceae | Lnp | GC |
| *Tridax procumbens* L. | Asteraceae | Ch | GC-SZ |
| *Triumfetta rhomboidea* Jacq. | Malvaceae | np | GC-SZ |
| *Vitellaria paradoxa* C.F.Gaertner subsp. *paradoxa* | Sapotaceae | mp | SZ |
| *Waltheria indica* L. | Malvaceae | np | GC-SZ |
| *Ximenia americana* L. | Oleaceae | mp | GC-SZ |
| *Ziziphus mucronata* Willd. | Rhamnaceae | mp | SZ |
| *Zornia glochidiata* Rchb. ex DC. | Fabaceae | Th | GC-SZ |