STRUCTURE AND ECOLOGY OF FOREST PLANT COMMUNITY IN TOGO

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FOLEGA F, ZHANG CY, WOEGAN YA, WALA K, DOURMA M, BATAWILA K, SEBURANGA JL, ZHAO XH & AKPAGANA K. 2014. Structure and ecology of forest plant community in Togo. Vegetation was sampled in 86 plots of riparian forest and dry forests of northern Togo. The recorded data were subjected to floristic and quantitative ecological analyses in order to describe the main woody plant communities and their size structure. The plant groupings were determined by detrended correspondence analysis (DCA) and defined through the indicator value method. Alpha diversity index, and tree species structure features were computed for forest woody plant groupings. Results classified four woody communities. Two of them belonged to riparian forest while the other two, dry forest. A total of 77 plant species consisted of woody species. *Pterocarpus santalinoïdes* and *Anogeissus leiocarpus* were the most important species based on their indicator values. The diversity indices of *P. santalinoïdes, Eugenia kerstingii* and *A. leiocarpus* and *Vitellaria paradoxa* plant communities were significant and indicated a wide distribution of species in the area, while their structural features reflected those of forests characteristic of the Sudanian climatic zones. In general, the natural regeneration rate among the plant groupings was satisfactory and quiet similar to those found in previous works in this region.

Keywords: Riparian forest, dry forest, plant grouping, *Pterocarpus santalinoïdes, Anogeissus leiocarpus, Vitellaria paradoxa,* regeneration, conservation

INTRODUCTION

Forests such as gallery, riparian and dry forest including woodlands of Africa are home to large numbers of flora and fauna species. Many of them are African endemics and have became threatened in the last several decades (O'Connor et al. 2007). The low investment in the forestry sector, increasing population pressure and weak public institutions affect forestry resource management, deforestation and forest service quality, thus threatening the ecosystems (Acharya & Kafle 2009, Seagle 2010).

In recent years, many works have been conducted in northern Togo, especially in protected areas to define and establish the floristic profiles of the vegetation in this region (Folega et al. 2010). These studies qualitatively revealed that forest ecosystems seemed to be much protected, while the adjacent shrubby, tree and woody savannas were under all kinds of human pressure.

In this region, agriculture fire (30.13%), tree cutting (30.35%) and transhumance (31.88%) are the top anthropogenic disturbances (Folega et al. 2012). These social and economic activities depend more on the availability of trees and water resources. It is well known that most water and wood are respectively concentrated in riparian and dense dry forest of this dry Sudanian zone (Ceperley et al. 2010, Sambare et al. 2011). The weakness of savanna ecosystem in providing response to the need of rural communities in terms of suitable soil for farming, water for cattle in dry season and wood for domestic cooking led to encroaches on forest area by the rural communities. Unfortunately, as far as research is concerned, there is lack of knowledge about the dynamism, structure and regeneration of forest woody species in this area. Thus current research could be a great contribution to the promotion of scientifically informed forest management policy.

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The research was focused in areas of important biodiversity. The main goal of this study was to describe the riparian and dry forests in savanna ecosystems by analysing the diversity of woody species. Specifically, it was aimed at finding out major forest woody plant communities and describing their floristic, ecological, dendrometric, dynamic growth and regeneration features.

MATERIALS AND METHODS

Study area

The survey area covered the protected areas of Barkoissi, Galangashi and Oti-Keran in Togo. It comprised the limit of the first demarcation of these protected areas (Sournia et al. 1998). The three protected areas are situated in Sudanian zone of Togo, which is dominated by savanna on leached ferruginous tropical soils. The study area is located between 10 and 11° N and between 0 and 1° E. The main relief within the study area is formed by a vast plain, which is dominated by leached ferruginous soils covering hardpan. The region has Sudanese tropical climate marked by alternation of long dry season and short rainy season. Monthly rainfall in a year ranges from 0.15 mm to 245.87 mm. Heavy rains occur in August and annual rainfall is about 1058.9 mm year^{-1}. Temperatures vary between 20 and 35 °C with an annual average of 28.5 °C at Mango meteorological station (Moussa 2008). The area is has two rivers, namely, Oti and Koumongou Rivers.

The anthropogenic influence on vegetation in the region is high. Major human disturbance activities by Ngamgam, Tchokossi, Lamba, Fulani ethnic groups include agriculture, firewood collection and agricultural fires. The main crop species are sorghum, millet, groundnuts, cowpeas, maize and yams, while the main livestocks are poultry, goat and sheep.

Data collection

Floristic sample plots of 30 m × 30 m and 50 m × 10 m were set up in dry forest and along rivers respectively. Square sample plots were established in dry forest, while rectangular plots were preferred along rivers and streams due to the linear structure of riparian vegetation. Plot sizes used were comparable with those commonly used in West Africa with

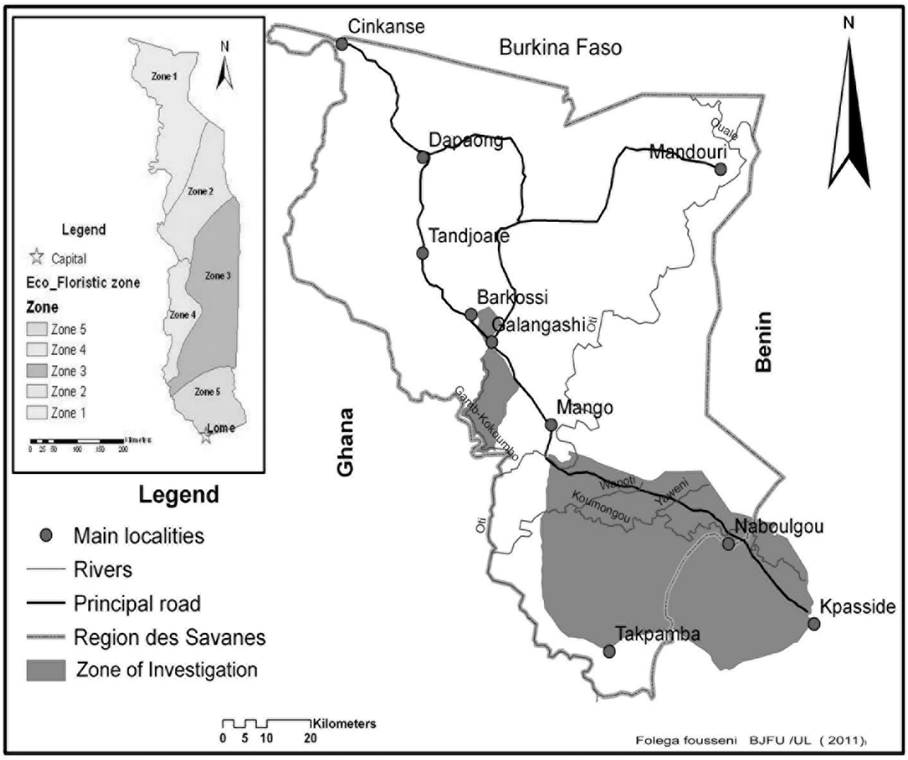

Figure 1 Location of study areas

few modifications in their shape design from one country to another. In Cote d'Ivoire the size commonly used was 25 × 25 m (N'Da et al. 2008) while in Togo and Benin, 900 and 500 m^2 were very common in vegetation sampling. The selection of 900 and 500 m^2 as minimum sample plot area was justified by the fact that they were successfully used in Togo and its neighbouring countries (Nacoulma et al. 2011).

The method used to collect data followed the phytosociological concept of Braun–Blanquet (Westhoff & van der Maarel 1978). In total, 86 samples were plotted in riparian and adjacent dry forests. All plant species were identified following Brunel et al. (1984). The species recorded in a given sample plot were assigned abundance/dominance coefficients as suggested by Westhoff and van der Maarel (1978): r = an individual, + = unimportant covering, 1 = less than 5%, 2 = 5–25%, 3 = 25–50%, 4 = 50–75%, 5 = more than 75%. Diameter at breast height (dbh) and height of tree individuals ≥ 10 cm were also recorded. For assessment of regeneration dynamics, the number of individuals with dbh < 10 cm was recorded including seedlings and suckers. Qualitative ecological characterisation, including edaphic variables (soils texture, structure, and submersion) as well as topographic attributes (slop, plateau, versant, valley and bank) and human disturbance factors (fire, farming, cutting and pasture) were recorded by field observation along with the geographical coordinates.

Data processing

A general checklist of species was established after digital processing of the 86 sample plots. The species were classified according to their phytogeographical types (White (1983), while their life form classification was based on definitions by Raunkier (1934).

Ordination in an indirect gradient analysis, specifically detrended correspondence analysis (DCA) (Ter Braak & Similauer 1998), was applied to a matrix of 86 samples × 77 tree species. The variables in the matrix were organised in presence/absence. The DCA analysis was carried out to extract major plant communities and highlight environmental factors frequently influencing tree species distribution. Species characterising plant grouping formed from DCA were determined on the basis of indicator value method (INDVAL) (Legendre & Legendre 1998). Specific abundance and frequency were computed for each species in a given grouping. An indicator value for a given tree species is obtained by multiplying its frequency of occurrence with its abundance. Among a batch of species which belonged to a procession of sample plots, two species with high INDVAL were retained for naming the plant grouping. The leading two species with high INDVAL could express that these species occurred at least in 50% of the sample plots which belonged to the assigned grouping.

Floristic features of the four tree plant communities were calculated to summarise and deduce information about the distribution of species. These features included species richness, Shannon–Weaver diversity index and Pielou's evenness (Kent & Coker 1992). Importance value index of individual tree species was calculated by summing up the relative values of specific frequency, density and dominance (Cottam & Curtis 1956). The dominance for a type of tree species was defined as the ratio of its basal area (G) to the total basal area. Below are the formula used to compute the different indices:

(1) Indicator value (INDVAL) = Ar × Fr × 100
where Ar = relative abundance and Fr = relative frequency

(2) Shannon–Weaver diversity index
$H' = \sum (Ni/N) \times \log_2 (NI/N)$
where Ni = number of samples in which the species i was present and N = total number of samples

(3) Pielou's evenness (E): $= H'/\log_2(S)$
where S = number of species

(4) Importance value index = Fri × Densri × Domri × 100
where Fri = species relative frequency, Densri = species relative density, Domri = species relative dominance

(5) Basal area (G) $= \sum D_i^2 \times 0.7854$
where G = basal area ($m^2\ ha^{-1}$), D_i = diameter (m) at 1.3 m above the ground and 0.7854 = $\pi/4$

To assess the dynamics and natural regeneration of tree species in these forest areas, the demographic structure of the defined forest woody plant community was evaluated through diameter classes. Their structural and dendrometric parameters such as average heights (Hm), average diameters (Dm), density of stems per hectare (D_{10}) and basal area were also calculated. The CANOCO® 4.5 and SPSS v. 18 Inc softwares were used to process the data.

RESULTS

Forest plant diversity overview

The investigation revealed a total number of 222 plant species (Appendix). These species belonged to 59 families and 162 genera. Eleven families were represented by at least more than 2% of taxon diversity. Fabaceae (13.9%), Poaceae (6.72%), Combretaceae (5.82%) and Euphorbiaceae (4.93%) were the most representative families (Figure 2a). Of the plant species found, 77 were woody species, among which *Ptreocarpus santalinoïdes*, *Anogeissus leiocarpus*, *Eugenia kerstingii*, *Mitragyna inermis*, *Cola laurifolia* and *Vitex madiensis* were the most dominant.

Phanerophytes were the dominant life form with microphanerophytes accounting for 22.76% of all recorded species, followed by nanophanerophytes (14.73%) and mesophanerophytes (13.39%) (Figure 2b). The riparian forest presented more mesophanerophytes (52.94%) and fewer therophytes (2.96%) than dry forest. The mesophanerophytes and microphanerophytes accounted each for 36.78% in dry forest. However, the proportion of herbaceous plant (8.66%) in this type of vegetation was higher than in riparian forest.

On chorological level, the Sudano–Zambezian (24.10%) followed by Guineo–Congolian (14.73%), Sudano–Guinean (14.28%) and Pantropical (13.83%) were the most important

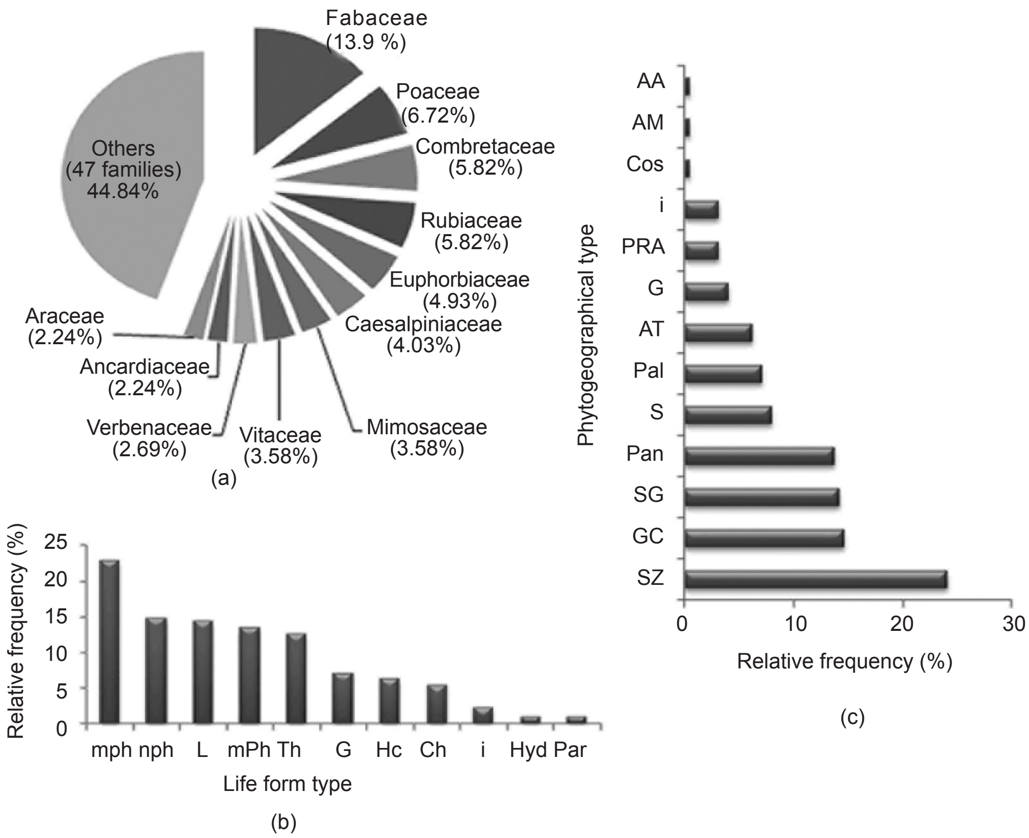

Figure 2 Overview floristic diversity of forest ecosystem: (a) diversity among family taxa, (b) life form type distribution; life form—mph: microphanerophytes, nph: nanophanerophytes, L: lianas, mPh: mesophanerophytes, Th: therophytes, G: geophytes, Hc: hemicryptophytes, Ch: chamephytes, i: undetermined, Hyd: hydrophytes and par: parasite, (c) phytogeographical type distribution; phytogeographical types—SZ: Sudano–Zambesian, GC: Guineo–Congolian, SG: Sudano–Guinean, Pan: Pantropical, S: Sudanian, Pal: Paleo-tropical, AT: Afro-tropical, G: Guinean, PRA: Pluri regional in Africa, i: undetermined, Cos: cosmopolitan, AM: Afro–Malgash and AA: Afro–American

phytogeographical types (Figure 2c). However, while Sudano–Zambezian species were important both in riparian and dry forest; the Guinean–Congolian and Sudano–Guinean species had higher proportion in the riparian forest (26.47%) than dry forest (6.89%).

Forest woody plant communities

Four forest tree plant communities were determined and identified following DCA. Samples that formed the clusters were well distributed between axis 1 and 3 of the factorial plan. The first four axis of the canonical plan expressed 19.5% of the total variance with total inertia of 10.4%. Axis 1 expressed gradient of water and moisture availability in the area. Plant groupings were arranged according to this environmental factor (Figure 3). From the left to the right side of axis 1, the first two forest woody communities (G1 and G2) represented the riparian forest, while the last two (G3 and G4) represented the dry forest.

The two dry forest groupings were located at a similar position along axis 1 and were well discriminated along axis 3 which expressed the degrees of topographic, edaphic and anthropogenous activities. In this landscape, the G3 dry forest was closer to riparian forest than G4 dry forest. However, G4, which was not immediately adjacent for the riparian forest, was close to savanna formation. The important proportion of *Vitellaria paradoxa* can be seen as a sign of the high degree of human activity in this dry forest compared with the rest of the forests.

Shannon–Weaver diversity indices for the four tree plant communities were between 2.53 and 4.45 bits, but Pielou's evenness indices were between 0.65 and 0.86 (Table 1). Group G4 had the highest indices of Shannon–Weaver and Pielou indices (Table 1). The importance value index computation applied to the 77 tree species of the area showed that *P. santalinoïdes* (69.29%), *A. leiocarpus* (28.86%), *E. kerstingii* (5.51%) and *M. inermis* (4.15%) were the most important tree species of the woody flora procession. The importance value index highlighted the important tree species which evolved in the study area. The high importance value index of *P. santalinoïdes* and *A. leiocarpus* were well in line with their indicator values according to which the plant groupings were determined.

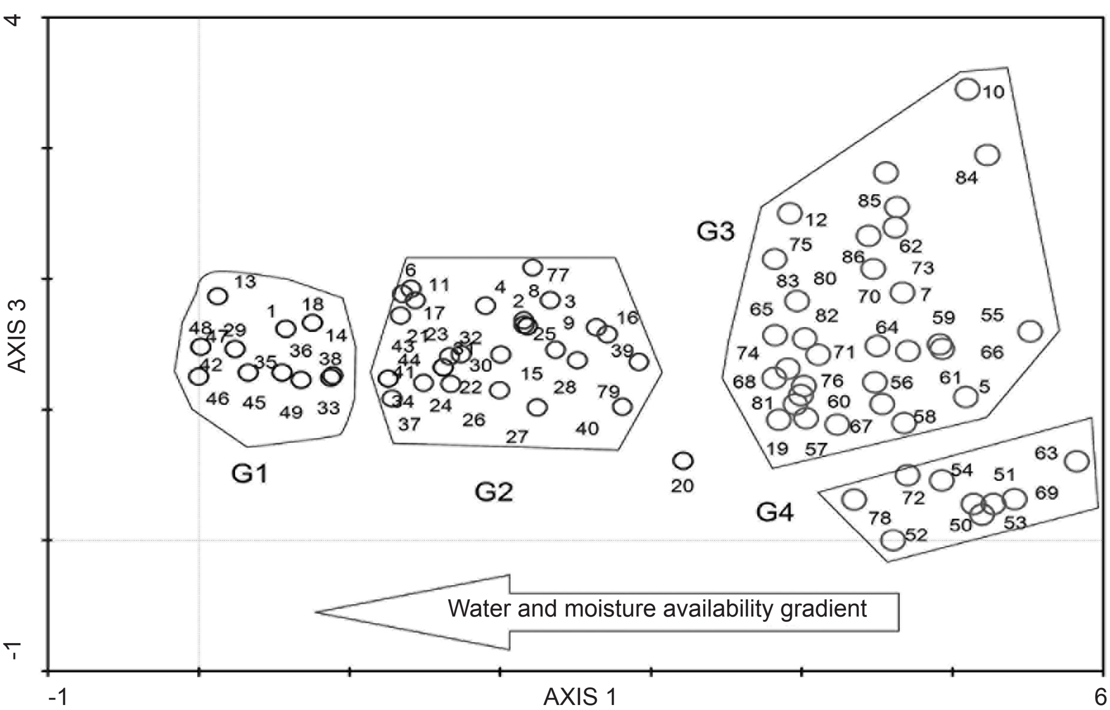

Figure 3 DCA ordination of 86 samples × 77 woody plant species; G1 and G2: riparian forests, G3 and G4: dry forests

Table 1 Diversity features of the four forest woody plant community in this study

Plant community	S ± SE	s	H' ± SE	s	E ± SE	s	INDVAL ± SE	s	Associated species
Pterocarpus santaloïdes & *Eugenia kerstingii* (G1)	10.00 ± 0.039	*	2.53 ± 0.001	*	0.80 ± 0.0003	*	9.08 ± 0.133	*	*P. santaloïdes, E. kerstingii, P. curatellifolia, M. discoidea, V. madiensis, F. capreaeifolia, C. laurifolia*
Pterocarpus santaloïdes & *Mitragyna inermis* (G2)	24.00 ± 0.054	**	3.06 ± 0.011	**	0.65 ± 0.0024	***	6.06 ± 0.087	**	*P. santaloïdes, M. inermis, E. kerstingii, V. madiensis, C. laurifolia, D. mespiliformis, A.leiocarpa, D. oliveri*
Anogeissus leiocarpa & *Pterocarpus erinaceus* (G3)	52.00 ± 0.053	***	3.99 ± 0.009	***	0.70 ± 0.016	**	6.68 ± 0.062	**	*A. leiocarpa, P. erinaceus, P. thonningii, M. inermis, T. laxiflora, D. mespiliformis, N. latifolia*
Anogeissus leiocarpa & *Vitellaria paradoxa* (G4)	35.00 ± 0.054	****	4.45 ± 0.001	****	0.86 ± 0.002	*	1.23 ± 0.023	***	*A. leiocarpa, V. paradoxa, S. birrea, C. molle, P. erinaceus, C. micranthum , E. abyssinica*

S =: species richness, H' = index of Shannon (bits), E = evenness of Pielou, s = significance level (grouping with the same number of asterisk are similar), SE = standard error of mean

Forest dynamics and regeneration

Size structure among tree plant communities is illustrated in Figure 4. Both plant groupings were characterised by high proportions of individuals belonging to 10–20 and 20–30 cm diameter classes but the G3 and G4 groups had more juvenile trees. Size distributions in the study area were best fitted with polynomial functions (Figure 4).

Basal area provided better measure for the relative importance of species than simple stem count (Table 2). It was clear that dendrometric parameters such as average height and average diameter in riparian forest (G1 and G2) were higher than those of dry forest. However, dry forest G3 presented low density compared with the three other groups. Its basal area was higher than that of G4.

DISCUSSION

The 222 plants species found in riparian and dry forests represented 81.38% of the total vascular species that existed in this area. This high proportion of species confirmed the fact that forest ecosystem in Sudanian climatic zone, especially riparian forests, were sanctuaries of biodiversity. It was also important to emphasise that the 77 woody species in riparian and dry forests were higher than the number of species recorded (68 species) in both ecosystems during previous investigation (Folega et al. 2011). The importance of woody species in this study was probably due to the fact that the investigation was conducted twice (during rainy and dry seasons). The average forest plant species richness in the Forest of Marahoue National Park (Cote d'Ivoire) (N'Da et al. 2008) was lower than the species record in this study.

The predominance of Fabaceae, Poaceae, Combretaceae and Euphorbiaceae families in this zone was confirmed by Folega et al. (2011) and Mbayngone et al. (2008). Tiliaceae was poorly represented in the Sudanian savanna of Senegal (Hejcmanova & Hejcman 2006). However, Fabaceae, Euphorbiaceae and Caesalpiniaceae reflected more on the existence of transition to the Guinean forest condition, while Combretaceae and Mimosaceae were also typical to Sudanian Endemism Center (Aubreville 1950). Contrary to the forests that evolved in tropical Guinean climate, Fabaceae, Rubiaceae and Euphorbiaceae represented the most important families (N'Da et al. 2008). The importance of Poaceae was due to the presence of open ecosystems close to riparian and dry forests and the influence of human disturbances (Kokou & Guy 2000).

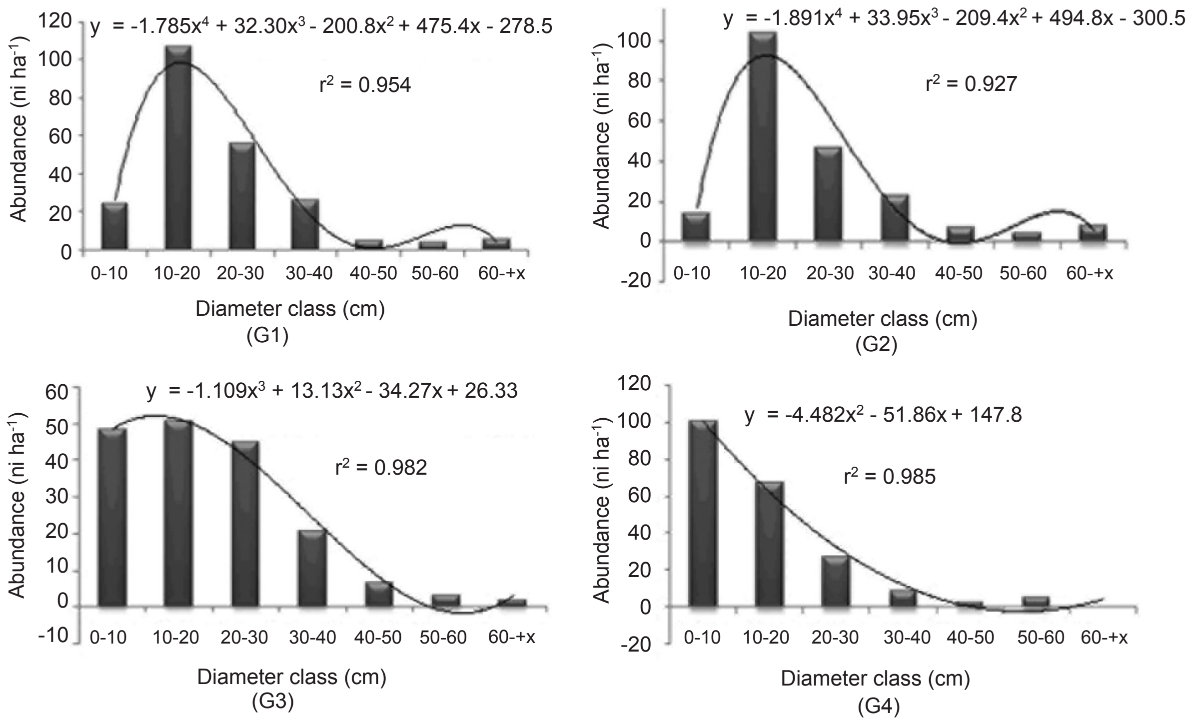

Figure 4 Diameter class distribution among each woody plant community; G1 and G2: riparian forests, G3 and G4: dry forests; G1 = *Pterocarpus santaloïdes* & *Eugenia kerstingii,* G2 = *Pterocarpus santaloïdes* & *Mitragyna inermis,* G3 = *Anogeissus leiocarpa* & *Pterocarpus erinaceus and* G4 = *Anogeissus leiocarpa* & *Vitellaria paradoxa*

Table 2 Summary of dendrometric features inside each woody plant community

PC	Hm ± SE	s	Dm ± SE	s	D_{10} ± SE	s	G ± SE	s
G1	12.36 ± 0.71	*	21.34 ± 0.87	*	228.63 ± 14.21	*	17.05 ± 0.008	*
G2	11.78 ± 0.37	*	23.60 ± 0.99	*	206.29 ± 13.58	**	52.79 ± 0.020	**
G3	9.59 ± 0.26	**	19.94 ± 0.58	**	175.00 ± 8.45	***	22.71 ± 0.002	***
G4	5.99 ± 0.34	***	13.94 ± 0.81	***	209.88 ± 16.27	**	4.09 ± 0.003	****

PC = plant community, Hm = average height (m), Dm (for dbh ≥ 10 cm) = average diameter (cm), D_{10} = density (number of samples ha^{-1}), G = basal area ($m^2\ ha^{-1}$), s = significant level (groupings with the same number of asterisk are similar), SE = standard error of mean; G1 = *Pterocarpus santaloïdes* & *Eugenia kerstingii,* G2 = *Pterocarpus santaloïdes* & *Mitragyna inermis,* G3 = *Anogeissus leiocarpa* & *Pterocarpus erinaceus and* G4 = *Anogeissus leiocarpa* & *Vitellaria paradoxa*

The woody structure of the study area was confirmed by the presence of phanerophytes (2–10 m in height) such as microphanerophytes, nanophanerophytes and mesophanerophytes (Folega et al. 2011). The same observation was made by Ceperley et al. (2010) in the riparian forest of central part of Benin. The presence of liana species was obvious as the study was conducted in the forest ecosystem but its high rate was more of an indication of ecosystem in reconstitution.

The species which belonged to the Sudanian Endemism Center (White 1983) was dominant and this was expected as it was suitable for the climate in the area. In total, 33.03% of species were found in the Guinean Endemism Center; this important proportion was due to the extension of the Guinean forest species in drought bioclimatic area (Bellefontaine et al. 1997). This importance proportion can be linked to the availability of water provided by the rivers.

Species distribution in the study area was mainly influenced by the presence of water (Figure 3). Topographic and soil conditions also affected the distribution. The soil at the study site was of clay–sandy or mud–sandy nature. Species found in this study except *P. santalinoïdes* and *E. kerstingii* were also found on sandy loam soils in Sudanian savanna of Senegal (Hejcmanova & Hejcman 2006).

The importance value index of *P. santalinoïdes* and *A. leiocarpus,* i.e. 69.29 and 28.86% respectively, suggested that they were the leading dominant species of the forest. In particular, the first species is typical of the riparian forest, which grows along the rivers of Sudanian or Sudano–Guinean zone. The riparian forest led by *P. santalinoïdes* was also mentioned in central and north Benin (Ceperley et al. 2010). The second species is common to dry dense or open forest adjacent to riparian forest. This was also reported in the research works conducted in the various protected areas of Togo by Kokou et al. (2006), Kossi et al. (2009) and Folega et al. (2010, 2011). However, in this study the groupings of *A. leiocarpus* was considered as dry forest. In the sub-Saharan massif of Jebel Marra (republic of Sudan) they were considered as riparian woodland (Ahmed 1983).

Structure parameters of the four forest plant communities reflected those of forest ecosystems in the Sudanian bioclimatic zone. The average height of trees in riparian forest was similar to height of the tree measures in riparian forest of central Benin (Ceperley et al. 2010). However, height of trees in the dry forest was very close to that recorded in the dry forest of Oti-Keran National park (Kossi et al. 2009) and in the dry and open forests in northern Benin (Sokpon et al. 2006). Densities of the four groupings in this study were much lower than those obtained by Kossi et al. (2009) and Sokpon et al. (2006). The polynomial tendencies of the diameter structure with high value of r^2 implied that tree plant communities in this area would be more disturbed because most of the time non-disturbed forest presented exponential tendency curve. The U-shaped population pattern clearly expressed that there was selective removal of individuals of preferred size of these species. High proportion of juvenile in G3 and G4 diameter class distribution was typical of natural forest regenerating from seeds (Rocky & Mligo 2012), but the inverse J-shape of their curve indicated a stable population structure (Nacoulma et al. 2011).

Tree basal area in National Park of Oti-Keran dry forest was 20.29 m^2 ha^{-1} (Kossi et al. 2009), while values reported in central and northern Benin were 21.91 (Sokpon et al. 2006) and 14.1 m^2 ha^{-1} (Bouko et al. 2007) respectively. Average dbh (13.05 ± 9.61 cm) in the dry forest of Oti-Keran National Park (Kossi et al. 2009) was much lower compared with those obtained in this study (Table 2).

The forest plant species regeneration followed a natural process by seedlings and suckers (Sokpon et al. 2006) as in most tropical forests. There is similarity between findings of this study and those of previous works done in the subregion. Among the five tree species with high potential of regeneration, *Isoberlinia doka* and *A. leiocarpus* were considered as first line species in terms of regeneration in dry and open forests (Kossi et al. 2009, Pare et al. 2009). In spite of having high potential of regeneration in savanna and forest boundaries, *A. leiocarpus* was also reported to be an important pioneer in the replacement of savanna by forest when fire impact was moderate (Hennenberg et al. (2005). Regeneration by suckers was more in ecosystems under the influence of disturbances (Kossi et al. 2009). Some authors have found that the dry forest can regenerate naturally only by preventing agriculture/bush fire in abandoned pastures (Janzen 2002) or anthropogenic savanna formations (Hennenberg et al. 2005). Based on field observations, dry forest seemed to be more disturbed by anthropogenous activities than riparian forest. The regeneration process in riparian forest both by seedlings (56.93%) and suckers (75.31%) was higher than in dry forest. For dry forest regeneration by seedlings was 43.06% while that by suckers, 24.68%. This confirmed that riparian forest in this area was also under disturbance. The low natural regeneration rate observed in dry forest maybe due to the water scarcity and less ground moisture availability. With regard to this physical factor, it was important to emphasise the impact of bush and agriculture fires, wood fuel harvesting, farming and pastoral activities, which seemed to be much severe on dry forest regeneration than on riparian forest. For any woody community, the absence or moderation of intensive human activities that resulted from the forest fencing encouraged and enhanced regeneration (Hejcmanova et al. 2009) and, thus, the loss of woody cover could be reversible in at least five years' time.

The structure, dynamics and regeneration potential were well in accordance with results from similar forests of the Sudanian bioclimatic area. Communities of woody species in West Africa were richer on arable soils (Devineau et al. 2009). However, the rate of diversity loss on these favourable soils also affected woody species.

CONCLUSIONS

With regard to human activities particularly transhumance, both riparian and dry forests as farmland faced the same issues. Water resource and the need for fuelwood were the principal reasons for people to leave the savanna ecosystem and settle within or in the vicinity of the main sanctuary of biodiversity in this drought area. Finally, it is urgent to rethink the policy and management approach for these forests that belong to the main protected area system.

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Appendix Species list

Family	Species	Phytogeographical type	Life form
Dicotyledon			
Acanthaceae	*Asystasia calycina*	G	Th
Amaranthaceae	*Achyranthes aspera*	Cos	Th
	Pandiaka involucrata	S	Ch
Ancardiaceae	*Anacardium occidentale*	Pan	mph
	Lannea acida	PRA	mPh
	Lannea kerstingii	SZ	mPh
	Lannea microcarpa	SZ	mPh
	Sclerocarya birrea	AT	mph
Annonaceae	*Annona glauca*	SZ	nph
	Annona senegalensis Pers.	SZ	nph
	Hexalobus monopetalus	SZ	mph
	Monanthotaxis parvifolia	G	Lnph
Araliaceae	*Cussonia kirkii*	SZ	mPh
Asclepiadaceae	*Gymnema sylvestre*	Pan	Lmph
	Leptadenia hastata	SZ	Ch
Asteraceae	*Aspilia bussei*	SG	Th
	Echinops longifolius	SZ	nph
	Vernonia colorata	SZ	mph
Balanitaceae	*Balanites aegyptiaca*	SZ	mph
Bignoniaceae	*Kigelia africana*	SG	mph
	Spatodea campanulata	GC	mph
	Stereospermum kunthianum	SZ	mph
Bombacaceae	*Adansonia digitata*	SZ	mPh
	Bombax costatum	SZ	mph
Boraginaceae	*Heliotropium indicum*	SG	Th
Caesalpiniaceae	*Afzelia africana*	S	mPh
	Cassia mimosoides	Pan	nph
	Cynometra megalophylla	GC	mPh
	Daniellia oliveri	SZ	mPh
	Detarium microcarpum	S	mph
	Erythrophleum suaveolens	SG	mPh
	Isoberlinia doka	S	mPh
	Piliostigma thonningii	S	mph
	Tamarindus indica	Pan	mPh
Caparaceae	*Crataeva adansonii*	Pal	mph
Celastraceae	*Maytenus senegalensis*	SZ	nph
Celtidaceae	*Celtis toka*	SZ	mPh
Chrysobalanaceae	*Parinari curatellifolia*	SZ	mph
Clusiaceae	*Garcinia livingstonei*	SZ	mPh
Cochlospermaceae	*Cochlospermum planchonii*	SG	nph
Combretaceae	*Anogeissus leiocarpus*	PRA	mPh
	Combretum acutum	S	Lmph
	Combretum collinum	SG	mPh
	Combretum fragrans	SZ	mph

(continued)

Appendix (continued)

	Combretum glutinosum	SZ	mph
	Combretum micranthum	S	mph
	Combretum molle	AT	mph
	Combretum paniculatum .	AT	mph
	Pteleopsis suberosa	PRA	mph
	Quisqualis indica.	Pal	Lmph
	Terminalia glaucescens	SG	mph
	Terminalia laxiflora	S	mph
	Terminalia macroptera	S	mph
Connaraceae	*Cnestis ferruginea*	GC	nph
Convolvulaceae	*Ipomoea aquatica*	GC	lnph
	Ipomoea argentaurata	S	Gr
	Ipomoea mauritiana	Pan	Lmph
Cucurbitaceae	*Citrullus colocynthis*	I	Th
	Colocynthis citrullus	AT	Th
	Luffa aegytiaca	Pan	Lnph
Ebenaceae	*Diospyros mespiliformis*	SZ	mPh
Euphorbiaceae	*Alchornea cordifolia*	GC	mph
	Bridelia ferruginea	PRA	mph
	Croton lobatus	Pan	Th
	Malotus oppositifollus	Pal	nph
	Margaritaria discoidea	SG	mph
	Phyllanthus muellerianus	SG	Lmph
	Phyllanthus reticulatus	SZ	nph
	Ricinus communis	Pan	nph
	Sapium ellipticum	AT	mph
	Securinega virosa	Pan	nph
	Tragia benthamii	GC	Lnph
Fabaceae	*Abrus precatorius*	SG	Lnph
	Aeschynomene schimperi	i	i
	Alysicarpus ovalifolius	Pal	Th
	Alysicarpus vaginalis	Pan	Th
	Baphia nitida	GC	mph
	Centrosema pubescens	GC	Lmph
	Crotalaria graminicola.	S	Th
	Crotalaria pallida	Pan	Ch
	Crotalaria retusa	Pan	Ch
	Desmodium gangeticum	Pal	nph
	Desmodium ramosissimum	Pal	Th
	Desmodium tortuosum	Pan	nph
	Desmodium triflorum	Pan	lnph
	Desmodium velutinum	Pal	Ch
	Erythrina senegalensis	SG	mph
	Indigofera dendroides	SZ	Th
	Indigofera spicata	GC	nph
	Indigofera trichopoda	SZ	Th

(continued)

Appendix (continued)

	Lonchocarpus laxiflorus	S	mph
	Lonchocarpus sericeus	PRA	mPh
	Millettia thonningii	GC	mph
	Pterocarpus erinaceus	SZ	mPh
	Ptreocarpus santalinoïdes	PRA	mPh
	Rhynchosia minima	GC	Lmph
	Sesbania pachycarpa	SZ	Th
	Tephrosia bracteolata	SG	Ch
	Tephrosia elegans	SG	Ch
	Tephrosia linearis	SG	Th
	Tephrosia purpurea	Pal	Ch
	Tephrosia villosa	Pan	Ch
	Uraria picta	Pal	nph
Lamiaceae	*Hyptis spicigera*	Pan	Ch
	Ocimum gratissimum	Pal	Ch
Loganiaceae	*Spigelia anthelmia*	AA	Th
	Strychnos barteri	GC	LmPh
	Strychnos nigritana	GC	LmPh
	Strychnos spinosa	AM	mph
Loranthaceae	*Tapinanthus dodoneifolius*	SZ	Par
	Tapinanthus pentagonia	SZ	Par
Malvaceae	*Hibiscus articulatus*	SZ	Hc
	Hibiscus asper	SG	nph
	Urena lobata	G	nph
	Wissadula amplissima	SZ	Th
Meliaceae	*Azadirachta indica*	Pal	mPh
	Khaya senegalensis	SZ	mPh
	Pseudocedrela kotschyi	SZ	mph
Menispermaceae	*Cissampelos mucronata* .	SZ	Lnph
	Tiliacora funifera	GC	Lmph
	Triclisia subcordata	G	Lnph
Mimosaceae	*Acacia dudgeoni*	SZ	mph
	Acacia gourmaensis	S	mph
	Acacia polyacantha	SZ	mPh
	Entada abyssinica	AT	mPh
	Entada africana	SZ	mph
	Mimosa pigra	Pan	nph
	Parkia biglobosa	Pal	mPh
	Prosopis africana	SZ	mPh
Moraceae	*Ficus capreaeifolia*	SZ	mph
	Ficus exasperata	GC	mPh
	Ficus sycomorus	SZ	mph
Myrtaceae	*Eugenia kerstingii*	GC	mph
Nymphaeaceae	*Nymphea lotus*	Pan	Hydr
Polygalaceae	*Polygonum senegalense*	AT	Hc
	Securidaca longepedunculata	AT	nph

(continued)

Appendix (continued)

Rhamnaceae	*Ziziphus abyssinica*	SZ	mph
	Ziziphus mucronata	PRA	mph
Rubiaceae	*Argocoffoepsis rupestris*	SG	mph
	Canthium horizontale	SG	Lnph
	Canthium multiflorum	SZ	nph
	Crossopteryx febrifuga	SZ	mph
	Feretia apodanthera	SZ	nph
	Gardenia aquala	SZ	nph
	Gardenia erubescens	SG	nph
	Gardenia ternifolia	Pal	nph
	Mitragyna inermis	SZ	mPh
	Morinda lucida	Pan	mph
	Nauclea latifolia	AT	mph
	Rytigynia canthioides	GC	mph
	Spermacoce ruelliae	SG	Th
Sapindaceae	*Allophylus africanus*	Pan	mph
	Cardiospermum halicacabum	Pan	Lmph
	Paullinia pinnata	AT	Lmph
Sapotaceae	*Manilkara multinervis*	SG	mph
	Vitellaria paradoxa	S	mPh
Solanaceae	*Lycopersicum esculentus*	i	i
	Physalis angulata .	Pan	Th
	Solanum tabacum	i	i
Sterculiaceae	*Cola laurifolia*	SG	mPh
	Sterculia setigera	SZ	mph
Tiliaceae	*Corchorus fascicularis*	Pan	Th
	Grewia cissoides	S	nph
	Grewia venusta	S	nph
	Triumfetta rhomboidea	Pan	nph
Ulmaceae	*Trema orientalis*	Pan	mph
Urticaceae	*Laportea ovalifolia*	GC	nph
Verbenaceae	*Clerodendrum capitatum*	GC	Lmph
	Lantana camara	SG	Lmph
	Premna quadrifolia	G	nph
	Vitex doniana	AT	mPh
	Vitex madiensis	SZ	nph
	Vitex simplicifolia	SZ	nph
Vitaceae	*Ampelocissus bombycina*	GC	Lmph
	Cissus araliodes	SG	Lnph
	Cissus lageniflorum	SZ	Lmph
	Cissus populnea	S	Lmph
	Cissus quadrangularis	SZ	Lmph
	Cissus vogelii	G	mph
	Cyphostemma griseo-rubrum	Pan	Lmph
	Cyphostemma sokodense	G	Lmph

(continued)

Appendix (continued)

Monocotyledon			
Amaryllidaceae	*Crinum ornantum*	SG	Ge
	Crinum jagus	GC	Ge
	Scadoxus multiflorus	SG	Gb
Araceae	*Amorphophallus flavovirens*	G	Gt
	Anchomanes difformis	GC	Gt
	Anubias gigantea	GC	Hyd
	Stylochiton hypogaeus	S	Gt
Arecaceae	*Elaesis guineensis*	GC	mph
Commelinaceae	*Aneilema beniniense*	GC	Hc
	Commelina erecta	AT	Ch
	Cyanotis longifolia	SG	Hc
	Murdannia simplex	AT	Hc
Cyperaceae	*Bulbostylis abortiva*	Pan	Hc
	Cyperus alternifolius	i	Gr
	Cyperus tenuiculmis	SG	Hc
Dioscoreaceae	*Dioscorea alata*	i	G
	Dioscorea dumetorum	SZ	Gt
	Dioscorea similacifolia	GC	Gt
	Dioscorea togoensis	GC	Gt
Liliaceae	*Asparagus warneckei*	G	Lmph
	Gloriosa superba	GC	LGb
Marantacea	*Marantocloa purpurea*	GC	nph
Poaceae	*Andropogon gayanus*	SG	Hc
	Andropogon tectorum	SG	Hc
	Brachiaria deflexa	Pal	Th
	Brachiaria lata	Pal	Th
	Cymbopogon nardus	i	Hc
	Echinochloa indica	SG	Th
	Hyparrhenia involucrata	SZ	Th
	Panicum maximum	GC	Hc
	Pennisetum subangustum	SG	Th
	Rottboellia cochenesinensis	Pan	Th
	Schizachyrium sanguineum	Pan	Hc
	Setaria barbata	Pan	Th
	Sporobolus pyramidalis	SZ	Hc
	Vitiveria nigritana	SZ	Hc
Taccaceae	*Tacca leontopetaloides*	Pal	G
Zingiberaceae	*Aframomum angustifolium*	GC	nph
	Costus afer	AT	Gr

Life form—mph: microphanerophytes, nph: nanophanerophytes, L: Lianas, mPh: mesophanerophytes, Th: therophytes, G: geophytes, Hc: hemicryptophytes, CH: chamephytes, i: undetermined, Hydr: hydrophytes and par: parasite; phytogeographical types—SZ: Sudano–Zambesian, GC: Guineo–Congolian, SG: Sudano–Guinean, pan: pantropical, S: Sudanian, Pal: Paleo-tropical, AT: Afro-tropical, G: Guinean, PRA: Pluri regional in Africa, i: undetermined, Cos: cosmopolitan, AM: Afro–Malgash and AA: Afro–American