academicJournals

Vol. 5(6), pp. 358-366, June 2013
DOI: 10.5897/IJBC12.061
ISSN 2141-243X © 2013 Academic Journals
http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Woody species diversity and important value indices in dense dry forests in Abdoulaye Wildlife Reserve (Togo, West Africa)

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Accepted 12 June, 2013

Dry forests are seriously under threats, mostly linked to human disturbance. In Togo where continuous deforestation is ongoing, it important to assess woody species diversity that maintain forest structure and functions. In that concern, this study was carried out in Abdoulaye Wildlife Reserve (AWR) with a specific objective to assess woody species diversity. A total of 258 plant species belonging to 119 genera and 63 families were found in AWR dry forests. Of this total, 67 woody species with 903 individuals and 52 genera were recorded. The highest relative frequencies were recorded by *Anogeissus leiocarpa* (83.37%), *Pouteria alnifolia* var. *alnifolia* (73.37%), *Cola gigantea* (50%), *Diospyros mespiliformis* (50%) and *Dialium guineense* (40%). The lianas species are dominated by *Rourea coccinea*, *Dioscorea dumetorum*, *Cissus populnea*, *Dioscorea burkilliana* whereas the dominated herbaceous of the undergrowth layer were *Anchomanes difformis*, *Chromolaena odorata*, *Olyra latifolia* and *Oplismenus hirtellus*. Three stand groups were revealed and the study highlighted trees bushfire and breakage as main threats on species diversity. These human pressures were highest in G_{III}. Globally, Pielou's index varied from 0.78 to 0.85. All these groups were dominated by *A. leiocarpa*. The study suggests conservation strategies to protect woody species against anthropogenic pressures (for example, protection from or reducing the frequency and/or intensity of disturbance, especially wood-cutting and bushfires).

Key words: Togo, biodiversity, woody species, sustainable management, dense dry forests.

INTRODUCTION

Dry forests and woodlands of Africa cover 54% of the continent and support some 64% of its population (CIFOR, 2011). Unfortunately, these forests are seriously under threats, mostly linked to human (Poorter et al., 2004) and climate change (Unmüßig and Cramer, 2008) impact. This implies the losses of biodiversity (Brockerhoff et al., 2008). In face of this significant concern, main concrete solution suggested during the last decade were forests plantation (Brockerhoff et al., 2008), effectiveness of protected areas in biodiversity conservation (Hulme and Murphree, 2001) and the enhancement of principles of sustainable use of forest resources (IUCN, 2001;

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ITTO, 2005; ITTO/IUCN, 2008). Thus, at regional scale as West Africa, this preoccupation is taking into consideration but local and national implication is highly recommended (Katerere et al., 2009). In Togo where deforestation is also continuously ongoing, many dry forests are converting to agricultural fields (Dourma et al., 2009; Adjonou et al., 2010). FAO (2010) pointed out that Togo is losing 5.1% of its forest cover net per year. Despite its location in the Dahomey Gap, an interruption of forested of Guinean forests (Poorter et al., 2004), little attention has been given to biodiversity safeguarding. This gap, by extension, is a part of the Guinean forests of West Africa classified as one of the world's 25 biodiversity hotspots (Myers et al., 2000). Therefore, the remnant tropical forests located there, especially dense dry forests must be seriously investigated and sustainably safeguarded with respect to their biodiversity's hotspot status. On the other hand, in Togo, the biodiversity investigations and inventories can provide a baseline for the national preparedness forests management policy. In the light of good forest governance, this policy seeks to increase the total forest cover of the country from the rate of 7% currently to 30% in order to be in line with the international certification criteria and indicators of forest sustainable management (ITTO, 2005; ITTO/IUCN, 2008).

As regard Abdoulaye Wildlife Reserve (AWR) so-called Reserve de Faune d'Abdoulaye mentioned by Togolese government in this preparedness, very few investigations have been carried out aside from Kokou et al. (2006) and Adjonou et al. (2010a). Therefore, reliable data on woody species diversity of forests stands in this specific area are required to minimize data scarcity and lack of consistency for a decision to be taken. This biological site also degrading at an alarming pace linked to two keys factors of land use change namely agriculture and illegal logging (Adjonou et al., 2010a). In addition, the insufficiency of data has become a genuine concern for forest managers, stockholders and scientists to include this protected area in their management planning. In order to address this issue and minimize data and scarcity and incongruousness for management planning and forest resources assessment of this protected area, this study focused on woody plant species diversity in AWR. The purpose was to contribute to national and inter-regional integration of AWR in protected areas database by providing reliable data according to international forest policies. The specific objective was to assess the woody species diversity in AWR.

MATERIALS AND METHODS

Survey area

The study area is situated between 08° 34' and 08° 46' north latitudes and 01° 13' and 01° 25' west longitudes. AWR is located in the ecological zone III (Figure 1) of Togo (Ern, 1979). The total area of AWR is 31868 ha (WDPA, 2006). The forest cover is 17563 ha (Kokou et al., 2006). Dense dry forests covered 4700 ha (Adjonou et al., 2010a). This area corresponds to lowland zone, with altitudes ranging from 243 to 359 m above sea level (Jarvis et al., 2008) in floodplain of River Mono. The climate is tropical Guinean type with unimodal rainy season generally lasts about 7 months, from April to October (Figure 2). The times series of environmental seasonality data (Hijmans et al., 2005) rainfall (derived from WorldClim) and vegetation index for the past 10 years from 2003 showed large inter-annual variability (EU, 2010). A typical year can be divided into one short hot (5 months) and one long rainy season (seven months: April to September). Maximum rainfall occurs during the monsoon season (July to September) with an average monthly rainfall of 25.27 mm. May has the highest average temperature (27.48°C). The vegetation is consisted of dense dry forests, open forests, gallery forests and savannas (Kokou et al., 2006; Adjonou et al., 2010b). The woody vegetation is dominated by Combretaceae, Sapotaceae, Sterculiaceae and Moraceae. Phytogeographically, AWR is located in the Soudanian regional center of endemism (White, 1986; Gauthier and Spichiger, 2004). Ferruginous soils are mainly encountered and resting on granite and gneiss bedrock (Lamouroux, 1969). These soils are rapidly degrading as a result of human activities as well as increased in population concentration.

In terms of socio-economics, AWR is located in a poorer area of the country where agriculture is the major occupation (Dourma et al., 2009). The population density is estimated at over 300 persons per square kilometer (RPGH, 2010).

Sampling design and data collection

The sampling method was based on line transect approach (Peres, 1999; Plumptre, 2000; Marshall et al., 2008) widely suggested to estimate relative density in tropical forests. Sample points along the linear transects were used to collect diversity data and to describe dry forests structure (Carlos and Lake, 2003; Terborgh et al., 2008). In each forest stand, between 7 and 12 sample points were ranged at fixed intervals along linear transects. A total of 30 square plots of 30 × 30 m size (Figure 3) were sampled with respect to previous study (Dourma et al., 2009). Two nested plots are separated from each other by 500 m. In each plot, the diameter at breast height and total height of each individual species were recorded. To assess the level of disturbance in the forest, the number of trees damage by breakage, harvesting, bushfire, and lopping or windthrow were recorded in each plot.

Data analysis

Wood species diversity

To analyze floristic data gathering from plot sampling and to describe AWR dense dry forests, the following parameters were considered. The threatened trees density (T, trees.ha^{-1}) was defined as average number of trees mutilated, scratched, burned, and dead or blow down per plot. These values were used to quantify the level of anthropogenic disturbance on each stand (area = 0.09 ha). The cover value index (CVI) of Förster (de Olivera-Filho et al., 1989) was used to evaluate the importance of woody species within the dry forest stands. CVI was calculated by adding relative density (RDe) and relative dominance (RDo) of species (de Olivera-Filho et al., 1989) while the importance value index (IVI) was calculated by adding CVI and relative frequency (RF) (Philips, 1959). These parameters data were obtained as follow:

RF = (frequency of species i / sum frequencies of all species) × 100,

RD = (number of individuals of species i / total number of individuals) × 100,

RDo = (total basal area for species i / total basal area of all species) × 100, The family importance value (FIV) was expressed by FIV = CVI + RDi. Where RDi (relative diversity) = (number of species i in family species i / total number of species) × 100.

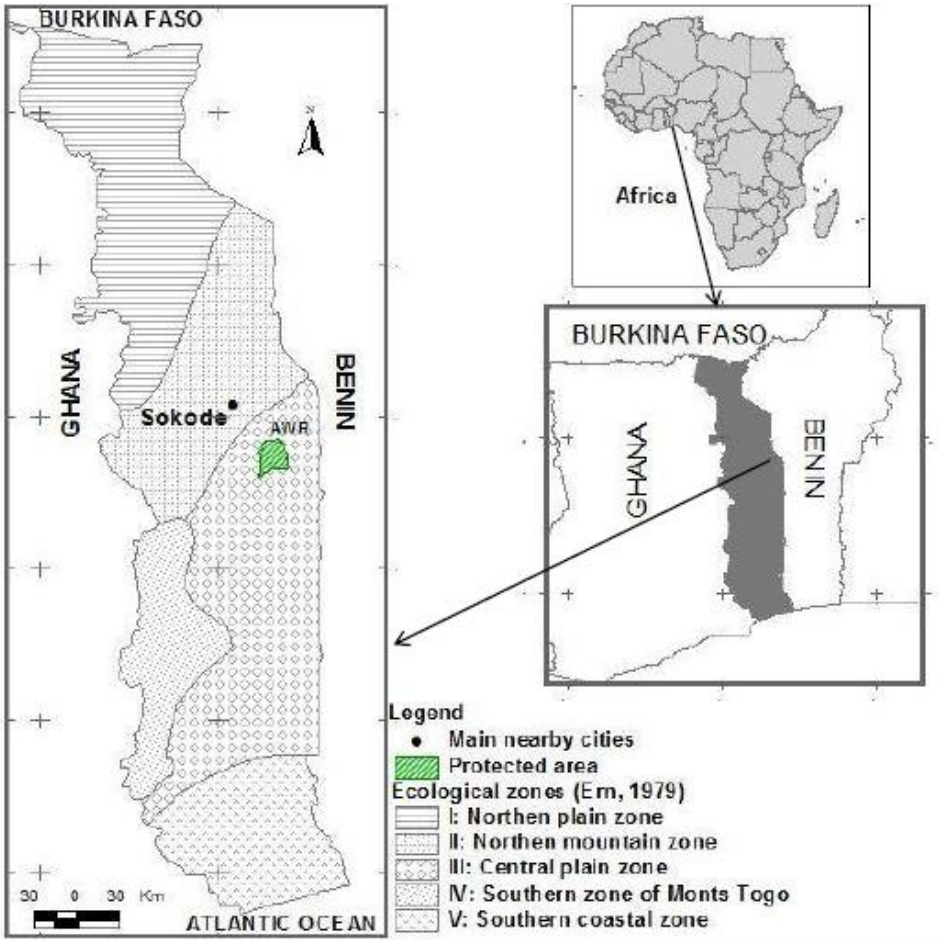

Figure 1. Location of Abdoulaye Wildlife Reserve with respect to ecological zones

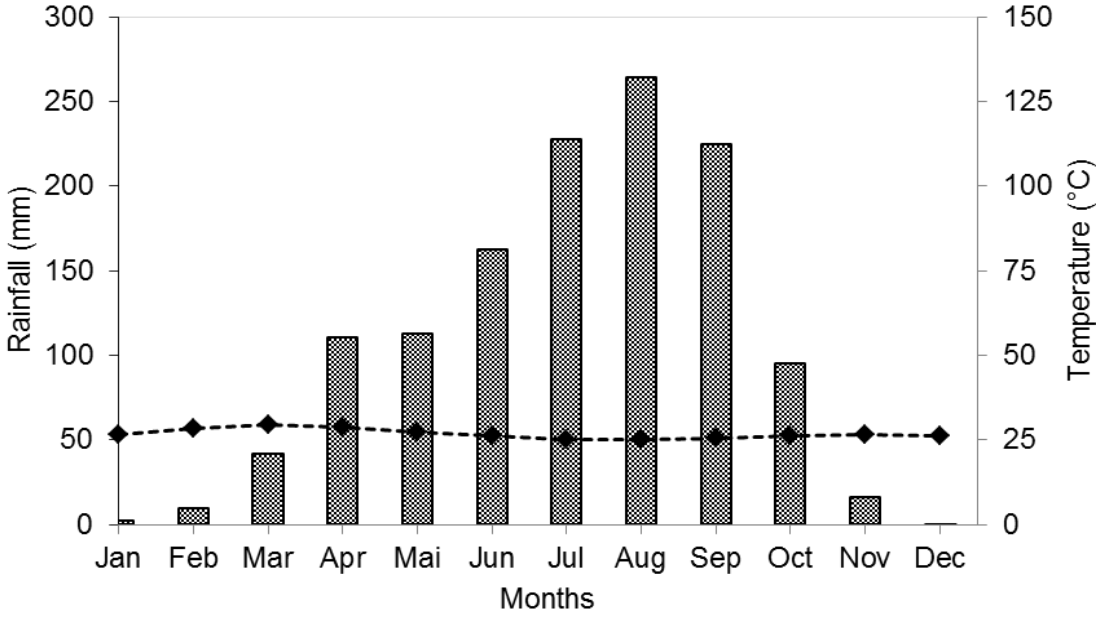

Figure 2. Rainfall, relative humidity and temperature data for the study area from January to December (mean of years 1981 to 2009): average rainfall (vertical bars); average temperature (diamond-shape).

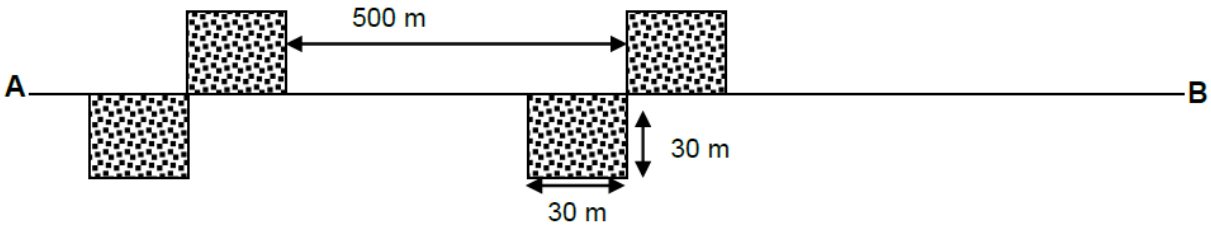

Figure 3. Plot design (A to B is the transect direction).

The alpha diversity indices were considered. The species pool (S) is the number of species recorded in the whole stand. The Simpson's reciprocal index (I_{SD}) is computed using the following formula:

$$I_{SD} = 1 - \frac{\sum_{i=1}^{n} n(n-1)}{\sum_{i=1}^{n} N(N-1)}$$

Where n is the number of trees of species i, N is the overall number of trees inventoried in the plot.

The Shannon-Wiener index (H) is obtained as follows:

$$H = -\sum_{i=n}^{S} p_i \, Log_2(p_i)$$

And Pielou's evenness (Eq) comparing the diversity of each stand was calculated as follows:

$$Eq = \frac{H}{Log_2(S)}$$

Where P_i is the proportion of the total number of individuals occurring in species i.

To detect stand groups, multivariate analysis was applied based on threatened trees density values. The cluster analysis to obtain the groups was performed by 'gradient analysis method' of direct canonical correspondence analysis (CCA) in Canoco® 4.51. The unimodal method performed was focused on inter-species distances (ter Braak and Smilauer, 2003).

RESULTS

Species composition

A total of 258 plant species belonging to 119 genera and 63 families were found in AWR dry forests. The highest relative frequencies were recorded by *Anogeissus leiocarpa* (83.37%), *Pouteria alnifolia* var. *alnifolia* (73.37%), *Cola gigantea* (50%), *Diospyros mespiliformis* (50%) and *Dialium guineense* (40%). The lianas species are dominated by *Rourea coccinea*, *Dioscorea dumetorum*, *Cissus populnea* and *Dioscorea burkilliana*; whereas, the dominated herbaceous of the undergrowth layer were *Anchomanes difformis*, *Chromolaena odorata, Olyra latifolia* and *Oplismenus hirtellus*. In terms of woody species, 903 individuals were encountered representing 67 species, 52 genera and 63 families. The three species with the highest stem number are *A. leiocarpa* (153), *D. mespiliformis* (106) and *P. alnifolia* var. *alnifolia* (66).

Diversity of dry forest groups

Based on species composition and density of threatened tree recorded, three vegetation groups were found: G_I, G_{II} and G_{III} (Figure 4). The main threats were trees bushfire and breakage. These human pressures were highest in G_{III} (Table 1). The Group G_I is composed of 7 plots. The species richness is about 107 all species considered and 20 woody species. The important value index (IVI) of the woody species mentioned *A. leiocarpa*, *P. alnifolia* var. *alnifolia*, *Spondias mombin*, *Pterocarpus erinaceus* and *C. gigantea* var. *gigantea* as the three dominant species. Their respective values were respectively 114.20, 89.21, 71.53, 70.72 and 69.90% (Table 3). The five rarest represented species are *Alstonia boonei* (16.86%), *C. populnea* (16.86%), *D. mespiliformis* (16.86%), *D. guineense* (16.05%) and *Erythrophleum africanum* (16.05%). This group can be considered as a typical dry forest of *A. leiocarpa*. However, in terms of family important value (FIV), families Sapotaceae (41.47%), Fabaceae (37.80%) and Combretaceae (33.49%) are the most represented (Table 5). The alpha diversity estimated by Simpson's reciprocal and Shannon's diversity index was 9.76 while the Pielou's index was 0.83 (Table 2). Group G_{II} is composed of 17 plots. The species richness was about 54 woody species and 204 when all species (woody and herbaceous plant species) were considered. *A. leiocarpa* (125.14%), *D. mespiliformis* (96.51%), *C. gigantea* var. *gigantea* (71.61%), *Manilkara multinervis* (71.18%) and *P. alnifolia* var. *alnifolia* (68.93%) recorded the highest IVI (Table 3). The rarest wood species were *Combretum racemosum* (6.10%), *Carissa edulis* (6.06%), *Parkia biglobosa* (6.06%), *Antidesma membranaceum* (6.06%) and *Landolphia dulcis* (6.06%). The FIV were 50.73, 50.22 and 33.59%, respectively for Combretaceae, Sapotaceae and Ebenaceae, the three most important family of G_{II}. The Shannon's diversity index was 4.49 bits. Group G_{III} was encompassed of 6 plots established. The species richness in G_{III} is about 149 all species considered and 36 woody species. The important value index (IVI) of the woody species mentioned *A. leiocarpa* (115.44%), *P. erinaceus* (93.18%), *D. mespiliformis* (85.92%), *C.*

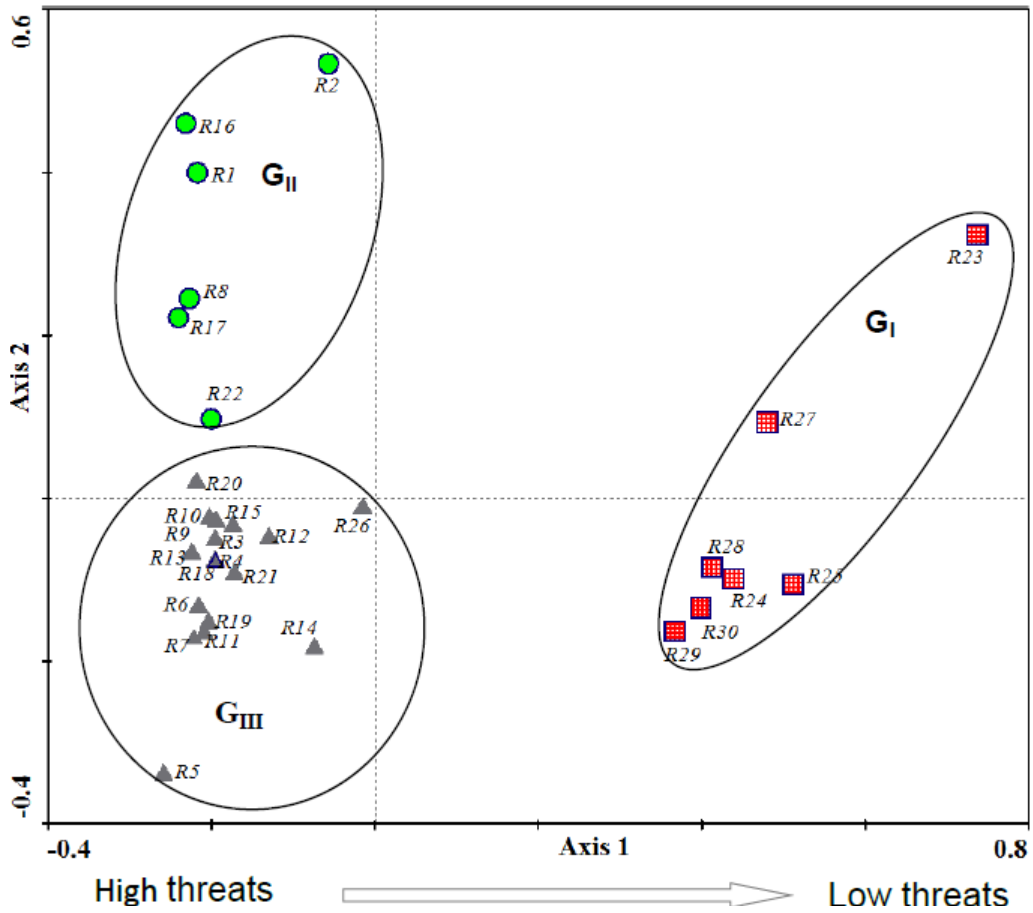

Figure 4. Projection of plot in the system axes of canonical correspondence analysis (CCA) using the threatened tree density.

Table 1. Densities of tree threatened recorded in AWR (tree.ha^{-1}).

Group	Wind throw	Breakage	Burning	Harvesting	Lopping	Total
GI	26	35	82	33	12	188
GII	42	34	88	19	0	183
GIII	43	204	252	0	22	521

Table 2. Alpha diversity characteristics of groups.

Indices	G_I	G_{II}	G_{III}
Species richness			
S	(20) 107	(54) 204	(36) 149
N	123	617	172
Diversity indices			
Simpson's reciprocal index (I_{SD})	9.76	13.87	14.54
Evenness indices			
Pielou's (Eq)	0.83	0.78	0.85

Number of woody species in bracket.

Table 3. The five most abundant species in each group according to decreasing order of the importance value index (IVI).

	Specie	RDe	RF	RDo	IVI
	Anogeissus leiocarpa	22.76	85.71	5.72	114.20
	Pouteria alnifolia var. *alnifolia*	13.01	71.42	4.77	89.21
G_I	*Spondias mombin*	10.56	57.14	3.81	71.53
	Pterocarpus erinaceus	9.75	57.14	3.81	70.71
	Cola gigantea var. *gigantea*	8.94	57.14	3.81	69.90
	Anogeissus leiocarpa	14.91	88.23	21.99	125.14
	Diospyros mespiliformis	14.58	64.70	17.22	96.51
G_{II}	*Cola gigantea* var. *gigantea*	3.07	58.82	9.71	71.62
	Manilkara multinervis	6.64	58.82	5.71	71.18
	Pouteria alnifolia var. *alnifolia*	7.29	52.94	8.70	68.934
	Anogeissus leiocarpa	19.76	66.66	29.01	115.44
	Pterocarpus erinaceus	6.97	83.33	2.87	93.18
G_{II}	*Diospyros mespiliformis*	8.72	66.66	10.53	85.92
	Cola gigantea var. *gigantea*	6.39	50	15.79	72.19
	Manilkara multinervis	7.55	50	05.21	62.76

gigantea var. *gigantea* (72.19%) and *M. multinervis* (62.76%) as the most abundant species. The IVI indicated *Strychnos innocua* (17.46%), *Piliostigma thonningii* (17.35%), *C. racemosum* (17.35%), *Annona senagalensis* ssp. *senegalensis* (17.34%) and *Albizia adianthifolia* (17.32%) as the rarest species (Table 4). Thus, G_{III} can be considered as an open forest derived from an undisturbed dense dry forest. The family Combretaceae (65.05%), Sapotaceae (38.24%) and Sterculiaceae (24.97%) recorded the highest FIV (Table 5). The alpha diversity through Simpson's reciprocal and Shannon's diversity indices were respectively, 14.54 and 4.39 bits; whereas, Pielou's index was estimated at 0.85.

DISCUSSION

AWR is significantly rich in plant species (258 species and 63 families). Kokou et al. (2006) reported the similar trends when assessing floristical diversity (265 species and 62 families) of protected areas in the centre of Togo. In their study, families Leguminoseae (Caealpiniaceae, Fabaceae and Mimosaceae), Rubiaceae and Moraceae were the most abundant recorded while in the present work, the FIV of each group revealed that dominant families were Combretaceae, Sapotaceae and Fabaceae. Our findings agree partially with the findings of Houehano et al. (2012) in Benin who reported globally the same observations when analyzing woody floristic in un- under protected areas. Wala et al. (2012) reported from an investigation in Aledjo reserve in Togo at the same latitude of our study area of 35 families, 74 genera and 94 species woody species, while we found 67 woody species and 52 genera. The suggestions of these differences should be linked to location of Aledjo reserve in Tchaoudjo mounts with particular environmental conditions such as in moisture and influences on rain fall. Our results agree with Adjonou et al. (2010a) who reported 69 woody species and 62 genera with 0.07% sampling rate in AWR when analyzing the spatial dynamic and dense dry forest structure of this protected area. Moreover, the number of plots sampled and its size can somehow explain this heterogeneity of the species richness. Our study revealed that the woody species richness was higher in Group G_{II} than in the others groups. The highest threatened trees density was observed in GIII. This suggests disturbance impact on woody diversity in AWR. The suggestions of this effect may be results in anthropogenic disturbances such as bushfire and breakage (Table 1).

Houehanou et al. (2012) pointed out that bushfires have a significant negative influence on woody species density especially in lower layer. This may be explained by the fact that human pressure open gap in the forest canopies through tree cutting or logging. Consequently, the lower layer is exposed to fire and other threats. Sapkota et al. (2009) studying the effective influenced of gap in tropical ecosystems dynamic found that artificially gap opened in canopy has a high disturbance impact on early growth of woody species. On the other hand, AWR has a wide diversity of vegetation type but under threats. Its location in river catchment with moist influences can explain this diversity. Therefore, the obtained groups differed basically each other by various characteristics. For instance, difference observed in families may result in stand variability, composition and structure (Wala et al., 2012). However, with influences from human disturbances, the diversity of stand will be varied (Savadogo et al., 2008, Sakpota et al., 2009). Thus, species will be more dominant than other depends on the habitat conditions (Sakpota et al., 2009). In our case, *A. leiocarpa* was

Table 4. The five rarest species in each group according to decreasing order of the importance value index (IVI).

Group	Specie	RDe	RF	RDo	IVI
	Alstonia boonei	1.62	14.28	0.95	16.86
	Cissus populnea	1.62	14.28	0.95	16.86
G_I	*Diospyros mespiliformis*	1.62	14.28	0.95	16.86
	Dialium guineense	0.81	14.28	0.95	16.05
	Erythrophleum africanum	0.81	14.28	0.95	16.05
	Combretum racemosum	0.16	05.88	0.05	6.11
	Carissa edulis	0.16	05.88	0.02	6.06
G_{II}	*Parkia biglobosa*	0.16	05.88	0.02	6.06
	Antidesma membranaceum	0.16	05.88	0.02	6.06
	Landolphia dulcis	00.16	05.88	0.02	6.06
	Strychnos innocua	0.58	16.66	0.23	17.46
	Piliostigma thonningii	0.58	16.66	0.10	17.35
G_{III}	*Combretum racemosum*	0.58	16.66	0.10	17.35
	Annona senagalensis	0.58	16.66	0.10	17.34
	Albizia adianthifolia	0.58	16.66	0.08	17.32

Table 5. The five most important families (sub-families) in each group according to decreasing order of family importance value (FIV).

G_I	Family	Sapotaceae	Fabaceae	Combretaceae	Anacardiaceae	Apocynaceae
	FIV	41.47	37.8	33.49	19.38	19.36
	Genera	2	3	1	1	2
	Species	2	3	1	1	2
G_{II}	**Family**	**Combretaceae**	**Sapotaceae**	**Ebenaceae**	**Mimosaceae**	**Caesalpiniaceae**
	FIV	50.73	50.22	33.59	17.97	17.02
	Genera	2	4	1	5	3
	Species	5	4	1	6	3
G_{III}	**Family**	**Combretaceae**	**Sapotaceae**	**Sterculiaceae**	**Ebenaceae**	**Caesalpiniaceae**
	FIV	65.05	38.24	24.97	22.03	20.32
	Genera	3	4	1	1	4
	Species	4	4	1	1	4

marked as the most present species. Our results are consistent with findings of Assogbadjo et al. (2009) and Hennenberg et al. (2005), who observed in protected areas a high dominance of *A. leiocarpa* in some mosaic savannah-forests respectively in Benin and Ivory Coast. That fact explained why the alpha diversity, the indices values were highly variable. This may be because of that species richness was strongly influenced by sample size of the stand groups. However, most indices showed that G_{II} was more diverse than G_{III} and G_I.

The calculated value of Pielou evenness index is similar in G_I and G_{III}. The Shannon-Wiener index calculated in this study fall within the usually expected range of Magurran (2004), that is, between 1.5 and 3.5 and rarely above 5.0.

Conclusion

AWR is significantly rich in plant species. A total of 258 plant species belonging to 119 genera and 63 families were found in AWR dry forests. Of this total, 67 woody species with 903 individuals and 52 genera were recorded. The highest relative frequencies were recorded by *A*. *leiocarpa* (83.37%), *P*. *alnifolia* var. *alnifolia* (73.37%), *C*. *gigantea* (50%), *D*. *mespiliformis* (50%) and *D*. *guineense* (40%). The lianas species are dominated by *R*. *coccinea*, *D*. *dumetorum*, *C*. *populnea*, *D*. *burkilliana*; whereas, the dominated herbaceous of the undergrowth layer were *A*. *difformis*, *C*. *odorata*, *O*. *latifolia* and *O*. *hirtellus.* Three stand groups were revealed and the study highlighted trees bushfire and breakage as main threats

on species diversity. These human pressures were highest in G_{III}. Globally, Pielou's index varied from 0.78 to 0.85. All these groups were dominated by *A. leiocarpa*. Therefore, conservation strategies to protect woody species against anthropogenic factors (for example, protection from or reducing the frequency and/or intensity of disturbance, especially wood-cutting and bushfires) should be taken to increase the abundance of rare species. Successful forest sustainable management implies the involvement of stakeholders, scientists with full agreement and participation of local communities.

ACKNOWLEDGMENTS

We are grateful to the Ministère de l'Environnement et des Ressources Forestières for permission to access Reserve de Faune d'Abdoulaye. This work was supported by Rufford Small Grants Foundation (RSG, England) for biodiversity conservation, International Tropical Timber Organization (ITTO, Japan) for professional expertise strengthening in tropical forestry and ACCFP Adaptation Science (Tanzania). We are grateful to two anonymous reviewers for constructive comments of earlier drafts of this paper. Special thanks go to the communities of Tchamba, Kousountou and Djome for their hospitality.

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