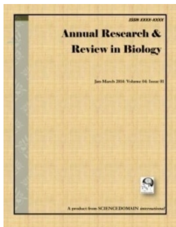

Annual Research & Review in Biology
4(15): 2501-2516, 2014

SCIENCEDOMAIN *international*
www.sciencedomain.org

Disturbance and Population Structure of Plant Communities in the Wildlife Reserve of Oti-Mandouri in Togo (West Africa)

Kangbéni Dimobe[1*], Kpérkouma Wala[1], Marra Dourma[1], Martial Kiki[3], Yao Woegan[1], Fousseni Folega[1,2], Komlan Batawila[1] and Koffi Akpagana[1]

[1]Laboratory of Botany and Plant Ecology, Faculty of Science, University of Lomé, P.O. Box: 1515 Lomé, Togo.
[2]The Key Laboratory for Silviculture and Conservation of Ministry of Education, Beijing Forestry University, Beijing 100083, People's Republic of China, China.
[3]Laboratory of Applied Ecology, Faculty of Agronomic Sciences, University of Abomey-Calavi, 01 P.O. Box: 526 Cotonou, Bénin.

Authors' contributions

This work was carried out in collaboration between all authors. Author KD wrote the protocol, performed the statistical analysis and wrote the first draft of the manuscript. Authors KD, KW, MD and YW realized the field works and managed the analyses of the study. Authors KW, KB and KA designed the study. All authors read and approved the final manuscript.

Original Research Article

Received 2nd February 2014
Accepted 29th March 2014
Published 18th April 2014

ABSTRACT

Aims: As a contribution to the sustainable management of protected areas in Togo, this study aims to analyze the impact of anthropogenic activities on plant communities in the wildlife reserve of Oti-Mandouri (North-Togo).
Study Design: The study area is located in the Sudanian zone, in northeast Togo.
Place and Duration of Study: The field work was carried out during April and June 2009, whilst processing data was done at Lab From July to October 2009.
Methodology: Total height and stem diameter at breast height (dbh) greater than 10 cm of all trees species were measured in 126 plots. In each plot, ecological parameters were recorded and the seedling and suckers (dbh<10cm) of species were counted.
Results: 116 woody species with dbh greater than 10 cm belonging to 33 families and 84

**Corresponding author: Email: kangbenidimobe@yahoo.fr;*

genera were listed. Presence/absence data of the overall species recorded in each plot was subjected to multidimensional scaling and results showed 4 types of woody vegetation: shrub savannas, tree savannas, wooded savannas and gallery forest. The most common families were *Rubiaceae* (14.28%), *Mimosaceae* (13.26%) and *Combretaceae* (11.22%). Species such as *Combretum glutinosum* (48.68%), *Mitragyna inermis* (36.84%), *Acacia polyacantha* (35.52%) and *Piliostigma thonningii* (35.52%) were relatively more frequent, but this potential floristic resource was almost threatened by human activities such as farming, grazing, burning, and tree cutting. The structure adjusted by 3-parameter Weibull showed reverse "J" shape for class diameter distribution with shape parameter varies between 1 and 3.6 showing a predominance of individuals with small diameter within the overall study area.

Conclusion: The results showed that this protected area is subjected to much degradation, and its conservation is important in the process of biodiversity conservation.

Keywords: Plant communities; biodiversity; human activities; wildlife reserve; management; Togo.

ABBREVIATIONS

DBH: Diameter at Breast Height; GPS: Global Positioning System; GIS: Geographic Information Systems.

1. INTRODUCTION

Research on protected area effectiveness has focused on potential benefits in terms of reductions in outright habitat loss, as well as habitat degradation [1,2,3].

African forest ecosystems in general and those of Togo in particular, suffer damage of various origins (Anthropogenic and natural disturbance). Human action is by far the largest [4,5,6,7,8]. In Togo, predominantly an agricultural based country, increasing demand for timber, fuel and construction and for traditional agriculture, by a rapidly growing population, put high pressure on limited forest resources [9,10,11]. Under this situation much of tropical biodiversity is unlikely to survive without effective protection and therefore strategies to promote its conservation are needed, for instance by establishing and maintaining protected areas [1]. This deforestation process has been reported for a long time by several authors, including [5,6,12]. This decline effects in both the dry deciduous forests and sudanian savannas located in the north of the country (Togo), composed of woodlands, dry forests and savannas. In savannas, the degradation process is exacerbated by the fact that even when crops are abandoned, they are regularly browsed by fire. According to [13] various human activities have disturbed savanna ecosystems for long time, as savannas are a resource for food, medicine, timber and livestock breeding [14].

In Togo, as in majority of developing countries, natural resources preservation was launched since precolonial period with sacred forests under traditional rules of nature protection and conservation [15,16]. These strategies were reinforced at the colonial and postcolonial period with the classification of several protected areas across the country including the wildlife reserve of Oti-Mandouri. Until 1990, 83 protected area were created. The postcolonial period was marked unfortunately by a hard semi-military management system. This management system was a source of conflict relationship between the forest managers and local populations. Thus, thanks to the sociopolitical crisis, the protected areas in Togo were occupied by bordering populations with occupancy rate varying between 15% and 100% [17]. Populations are reinvesting their old lands and practice traditional socio-economic activities such as itinerant agriculture, fishing, hunting, wood exploitation (fuel wood and timber), medicinal plants harvesting, etc.

The reserve of Oti-Mandouri was classified in 1981 [6]. Thanks to several natural pools and large watercourses, birds' fauna is still diversified and abundant, with migratory birds among others. In this reserve is a huge human pressure on land. Several anarchistic and clandestine activities are carried out and are real threats for its biological richness and the integrity of its ecosystems. Moreover, degradation of vegetation and fauna habitats as well as overexploitation of particular useful species was observed [6]. Impacts include direct competition and conflict between wild animals, farmers and herders, for space and grazing; disturbance to wildlife (with the complete absence of large and small mammal fauna in most areas); loss of biodiversity (including local extinction of species) and loss of ecosystem integrity and degradation of habitats (soils, natural vegetation, erosion in and around seasonal lakes and marshes and permanent watercourses. In that situation, this reserve does not ensure its role of protection and conservation *In situ* of biological diversity. Actions must be taken for a sustainable conservation of protection of its biological diversity by setting an effective management scheme. The lack of any effective land use planning, the complete breakdown of respect for protected areas and absence of enforcement of the legislation to regulate exploitation (e.g. transhumance) means that all these activities are being pursued in uncoordinated and unsustainable ways which damage the environment and threaten the natural resource which is essential for both people and wildlife.

This study was undertaken to contribute to the sustainable management of the wildlife Reserve of Oti-Mandouri. It aims to analyze the impact of anthropogenic activities on plant communities structure in the wildlife reserve of Oti-Mandouri.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in the Oti-Mandouri wildlife Reserve, a protected area located in the extreme north-eastern part of Togo (West Africa) and in its surrounding land use areas. It is geographically located in the Sudanian zone [18], between 10º18'-11º and 0º30' - 0º47' (Fig. 1), it belongs to the Ecological zone I (Northern plain) [19] which belong to Volta basin is constituted of sandstones, pelites and silica tillite, carbonates, chert and shales. The plain is drained by many rivers such as Oti, Koumongou, Wapoti Yaweni, Komkoumbou and Gambara. This reserve was linked to the WAP complex (Burkina, Benin, Niger) until a socio-political crisis started in 1990. The reserve covers an area of about 110,000 ha [20]. In the protected area anthropogenic activities are strictly prohibited while the surrounding areas are dominated by farmlands, fallows and savannas. The savannas in the surrounding unprotected areas are all subjected to selective logging and cutting of valuable tree species, carbonization, itinerant agriculture, livestock grazing and or non timber forest products harvesting. Climate is characteristic for tropical African regions with two seasons: A rainy season June - October and a dry season November - May, with an average of 6–7 dry months. Total rainfall is between 800 and 1000 mm. Temperatures vary between 17 and 39ºC during the dry season and between 22 and 34ºC during the rainy season. The predominant vegetation is Sudanese Savanna, with some dry forest patches and gallery forests along the rivers. The Sudanese Savannas in the northern part of the country are part of the most vast and important eco - geographical regions for migration of West African Elephants (*Loxodonta africana*) and other rare species. However, indurate tropical ferruginous soils and swampy tropical ferruginous soils are mainly distributed in sampled area of protected and unprotected areas. Vegetation formation is characterized mainly by woodlands and savannas in the protected and land use areas with predominance of Mimosaceae (*Acacia spp*) and *Combretaceae* (*Combretum spp* and *Terminalia spp*). This reserve is labeled in category IV of IUCN list [20].

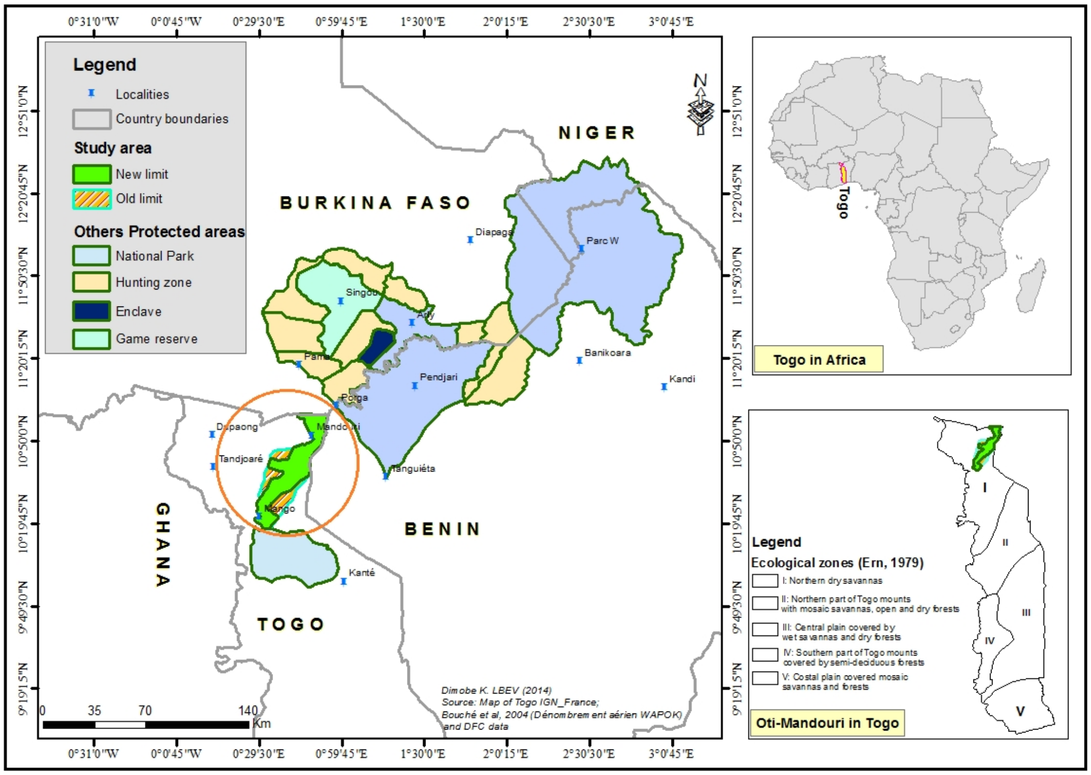

Fig. 1. Localization of the study zone

2.2 Sampling Design and Data Collection

To characterize the vegetation of this reserve, surveys were carried out in several sites representing the variation in vegetation and topography. Thus, plots were installed along twenty transversal transects from the eastern to the western sides of the reserve. A minimum of three plots per transect was installed. The number of plots increased for transects located in complex topographical zones. Ecological data were investigated in 126 plots, which size varied following the vegetation type. The plots are rectangular in gallery forest and square in savannas with a total area of 500 m² [21] and 900 m^2 [5,6,12,22] respectively. They were spaced at least by 100 m along the transects.

In each plot, all plant species of tree layers and several ecological variables were recorded: topography (slope, landscape position), vegetation cover using the Braun-Blanquet method

[23], human activities, soil texture and moisture. Ecological data relating to all the species having at least 10 cm dbh were recorded. In addition, the diameter of all tree species (dbh ≥ 10 cm) was measured within each plot as well as the total height of individuals. Moreover, adjacent diagonal 10 m x 10 m subplots were established within each plot for the natural regeneration study [24,3]. All the individuals exploited either for the energy or service, timber or as medicinal plants were enumerated. To this end, the stumps of the cut individuals were identified and counted [5]. The geographical coordinates of floristic inventory plots and the human footprints along transects were recorded using the Global Positioning System (GPS) GARMIN for spatial analysis.

2.3 Data Analysis

The presence/absence data of all inventoried species within the 126 plots were grouped in a binary matrix ("Plots x species") and submitted to Detrended Correspondence Analysis (DCA) [25] according to the method of Ward with the Community Analysis Package (CAP) version 2.15 software. This analysis had allowed to define plants communities' groups.

For each identified group, ecological and dendrometric parameters were calculated.

Three indices were chosen for estimation of diversity [26,27]:

1. Species richness S represented by number of species recorded in each vegetation type
2. Shannon–Wiener's index of diversity (*H'*)

$$H' = -\sum_{i=1}^{s} \frac{Ni}{N} \log_2 \frac{Ni}{N}$$

Ni is the number of individuals of species *i*, *N* is the overall number of trees inventoried in the plot.

3. Pielou's index of evennes (*E*)

$$E = \frac{H'}{H'max} \qquad \text{With } H'max = \text{Log}_2 S$$

H'max is the maximum value of the Shannon's diversity index of the stand, and *S* is the number of vascular species recorded in the considered plot.

On the other hand, the mean diameter of the trees (*Dm* in cm), basal area of the stand (*G* in m^2/ha) and the Lorey's mean height (*HL*, in m), i.e. the average height of all trees found in the plot, weighted by their basal area [28], was computed.

To establish the stem diameter structure of each plant community, all individuals were grouped into diameter classes of 10 cm in order to obtain enough diameter classes (at least 10). Size class distributions were adjusted to 3-parameters (*a, b, c*) Weibull theoretical distribution [24,29] because of its flexibility [30]. This theoretical distribution has the ability to describe a wide range of unimodal distributions including reversed-J-shaped, exponential and normal frequency distributions [31]. The tree densities were assessed for diameter classes. As far as the height structure is concerned, classes with 2 m amplitude were considered. The observed different diameter structures were adjusted to the 3-parameter-Weibull distribution because of its flexibility [32], whose density function, *f* is expressed for a tree-diameter *x* as follows:

$$f(x) = \frac{C}{b}\,(\frac{x-a}{b})^{c-1}e^{\left[x-\frac{a}{b}\right]C}$$

Where *x*= tree diameter; *a* = 10 cm for the diameter structure and 2 m for the height structure; *b*= scale parameter linked to the central value of diameters and heights; *c* = shape parameter of the structure.

For each identified group, diameters of trees were used to estimate the parameters b and c based on the maximum likelihood method [32]. The log-linear analysis [33] was performed in SAS [34] for each case to test the adequacy of the observed structure to the Weibull distribution.

3. RESULTS AND DISCUSSION

3.1 Floristic Analysis

116 woody species (dbh ≥10 cm) were identified after data analysis from the floristic inventory. These species which are grouped into 33 families and 84 genera, corresponds to 2.80 % of flora of Togo. 116 woody species (dbh ≥10 cm) were identified after data analysis from the floristic inventory. These species which are grouped into 33 families and 84 genera, corresponds to 2.80 % of flora of Togo. This number of woody species (116) is higher than those recorded by [5] in the protected area of Alédjo (94 woody species). This might be attributed to the number of plots in which they've worked (47 plots against 126 plots in our study area). However, this number of species that we've recorded is lower than those recorded by [12,35,36,37] respectively in Oti prefecture protected areas(in the same ecological zone), the Fazao-Malfakassa national park and the fauna reserve of Aledjo (central part of the chain of Atakora) (617 species) and in the septentrional part of the same chain (Benin) (663 species). This wide variation might have been due to climatic differences (because the Atakora Mountain chain belongs to Guinean tropical climate which is more humid than Sudanian one) and the fact that they have worked on woody and herbaceous species. The most common families were *Rubiaceae* (14.28 %), *Mimosaceae* (13.26 %) and, *Combretaceae* (11.22 %). Frequency curve showed that a small number of species: *Combretum glutinosum* (48.68 %), *Mitragyna inermis* (36.84 %), *Acacia polyacantha* (35.52 %) and *Piliostigma thonningii* (35.52 %) were relatively more frequent (> 30%) while a large proportion of species are rare. The *Combretaceae* and *Mimosaceae*, indicator of a generally dry climate [38] are dominant and pervasive in this study area located in the northern region of Togo. This is due to low rainfall and high temperatures which translate the aridity of sudanese climate. This floristic trend has been reported by [39,40] respectively in Burkina and in Benin. This trend is characteristic of African sudanian savannas. However, the emergence of Rubiaceae is a feature that is linked to the large gallery forest along the Oti River.

The Sudano-Zambesian (SZ) and Sudanian (S) species were the most recorded representatives on phytogeographical level (Fig. 2). The species SZ (28 %) and S (21%) correspond to the major phytogeographical types of the reserve. Their dominance has also been reported by [37,41] in the Sudanian zone. This is also a proof of plant communities' floristic originality of sudanese endemism's domain. The presence of the Guineo-Congolian (GC) species is due to the water system density favorable to the development of a relatively hygrophilic flora. Whereas the remarkable presence of pantropical (Pan) and Pluri-Regional (PRA) species show anthropogenic pressure in this protected area.

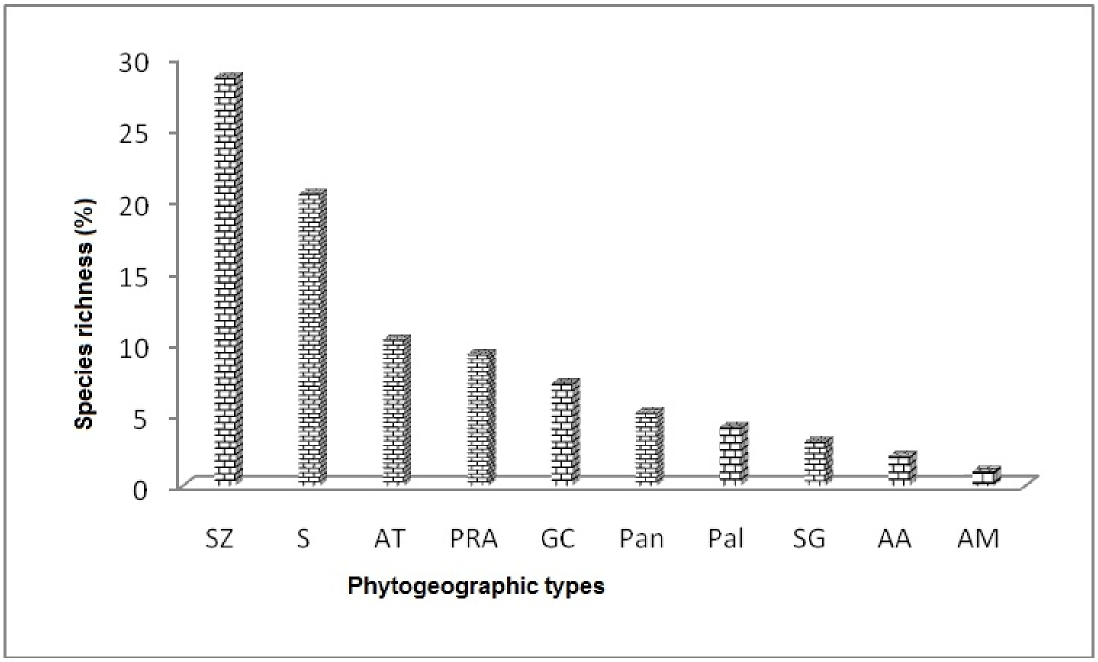

Fig. 2. Phytogeographic types frequency distribution in the Wildlife reserve of Oti-Mandouri (SZ: Sudano-Zambezian, GC: guineo-congolian, S: sudanian, AT: afro-tropical, Pan: pantropical, PRA: Pluri-Regional in Africa, SG: sudano-guinean, Pal: paleotropical, AM: afro-malagasy, AA: afro-asiatic)

3.2 Discrimination of Habitats Groups and Tree Species Composition

Variation in floristic composition indicated four vegetation groups: G1, G2, G3 and G4 (Fig. 3). The first axis discriminates the open vegetations (G1, G2 and G3) from the closed one (G4 along streams) Along this axis 1 are laid out successively from the left-hand side towards the right, the shrub savannas, tree savannas, Savanna woodland and gallery forest. This axis indicates an edaphic gradient and discriminates formations shallow soils and gravelly (left) of those with deep soils and clay (to the right). The same axis indicates that the relative moisture of the soil increases as one move from left to right. This moisture gradient also induces a gradient of closure or density of vegetation. The second axis does not discriminate gradient.

Diversity indices and structure parameters vary from one group to another (Table 1). Compared to the total wealth of each group defining species of vegetation, gallery forests and tree savannas species totaling more with respectively 46 and 38 species. Woodland savannas recording fewer species (29 species). Regarding the Shannon diversity index (*H'*) calculated, Savanna woodland and gallery forests are more diverse with respectively *H'* = 4.61 bits and H' = 4.43 bits. Pielou index (*E*) shows a limited number of species which prints the physiognomy of all the four vegetation types. These are in order of importance value index, Savanna woodland (*E* = 0.83), tree savannas (*E* = 0.78), gallery forests (*E* = 0.74) and savannas shrub (E = 0.72).

Table 1. Structural characteristics of vegetation types

Parameters	G1: Gallery forest	G2: Savanna woodland	G3: Tree savanna	G4: Shrub savanna
Species richness (*S*)	46	29	38	34
Shannon's diversity (*H'* bits)	4.43	4.61	3.84	3.43
Pielou's evenness (*E*)	0.74	0.83	0.78	0.72
Heigh (m)	8.72	9.36	8.83	6.90
Basal area (*G* m² per ha)	67.26±28.5	25.90±11.3	22.76±9.1	40.63±20.63

In addition, by focusing on the basal area (*G*), plant communities with high values are gallery forests with *G* = 67.26±28.5 m² / ha and, shrublands with *G* = 40.63±20.63 m²/ha. The lowest values of basal area are observed in Savanna woodland and in Tree savanna.

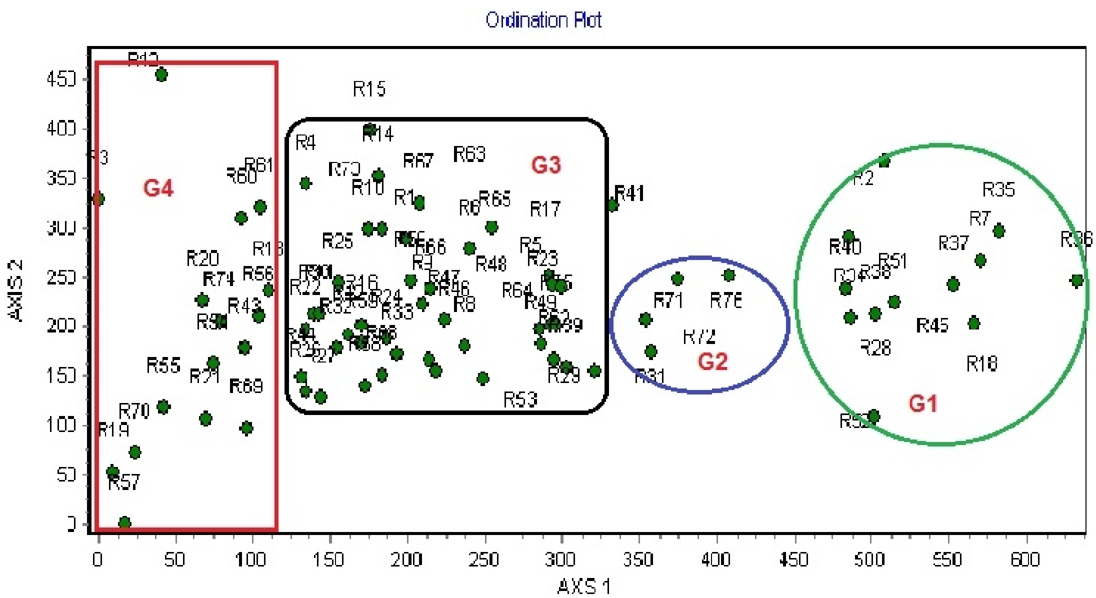

Fig. 3. Detrended Correspondence Analysis (DCA) showing discrimination of plots by species composition. (G1: Gallery forest, G2: Savanna woodland, G3: Tree savanna, G4: Shrub savanna)

The study allows the identification of four types of vegetation in this Sudanian savanna ecosystem. These kinds of vegetation are typical and represent the major feature of the vegetation component which can be met in this area [6]. The same vegetation type was described in the protected area of Oti-Keran by [12].

3.3 Diameter Classes Structure

In this part, we consider only the structure of gallery forests, savanna woodlands and tree savannas.

The size class distributions of the species were analyzed for gallery forests (Fig. 4). The diameter class distribution showed a reverse “J” shaped curve. Size class distributions of species are constructed within protected and unprotected gallery forests. In both gallery forest types the species has a *c*-value comprised between 1 and 1.8. The 10 – 40 cm dbh classes are the most represented in both habitat types. Juveniles are most represented respectively in protected gallery forest. Individuals of large diameter classes (dbh > 70 cm) are absent in unprotected compared with protected habitats. The results show that in the protected gallery forest juveniles and adults’ trees are most represented than in unprotected ones.

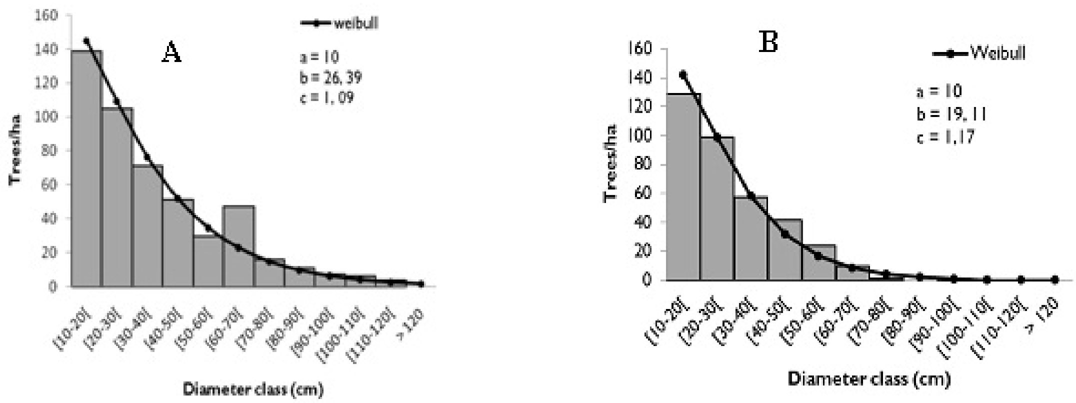

Fig. 4. Size class distribution of tree species in protected gallery forest (A) and unprotected gallery forest (B)

As far as Savanna woodlands are concerned, size class distributions were built in protected and unprotected habitats (Fig. 5). This diameter distribution shows a bell shape distribution for both habitat and a left dissymmetric distribution.

In all habitats *c*-value is comprised between 1.89 and 1.98. Individuals of dbh > 10 cm are less present in unprotected than in protected savannas.

Juveniles are most represented in protected savanna than unprotected savanna.

Regarding tree savannas, the diameter class distribution showed a reverse “J” shaped curve (Fig. 6). The *c*-value is comprised between 1 and 1.5. In the overall stand, trees with 10-30 cm were more abundant in protected tree savannas than in unprotected. The “J” distribution observed within the different groups ($1 < c < 3.6$) means a stands with a predominance of trees with small diameter (dbh) [30].

The diameter structure of the plant communities is asymmetric positive indicating that the stands were dominated by small diameter individuals ($1 < c < 3.6$). Diameter classes in bell showed the best representation of middle diameter individuals. The observed structure was similar to the one observed by [42] and [43] respectively in the Sudanian Zone of Togo and in the hills Park of Zoundwéogo and Nahouri in the oriental part of the Burkina Faso. The same structure had been described by [24] for *Afzelia africana* in the Lama Forest reserve of Benin.

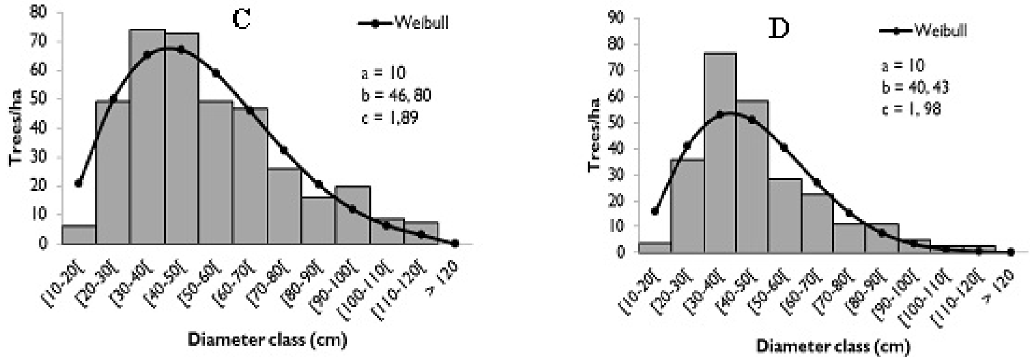

Fig. 5. Size class distribution of tree species in protected Savanna woodland (C) and unprotected Savanna woodland (D)

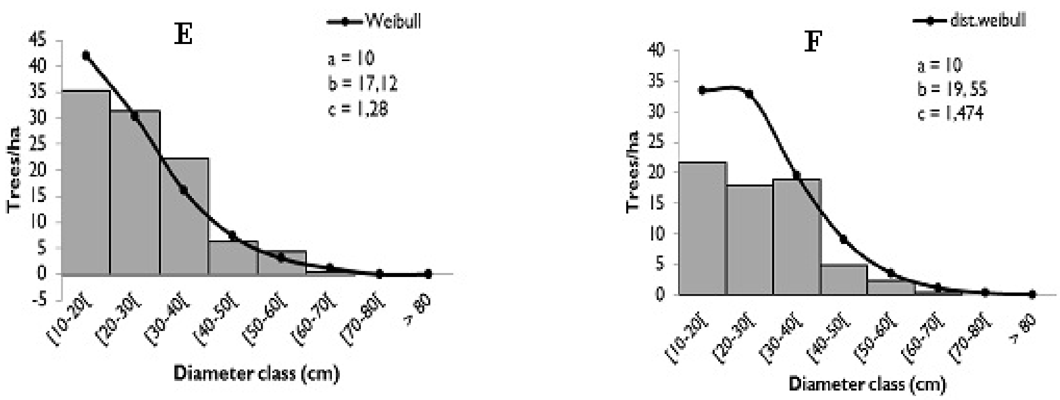

Fig. 6. Size class distribution of tree species in protected tree savanna (E) and unprotected tree savanna (F)

In this protected area, size class distribution of tree species are affected by many factors such as human disturbance [44,45,2,46] as described by [47].

The densities of juveniles for species revealed higher values in protected habitats compared to unprotected ones. This means that protection is effective to preserve more juveniles of these species.

Due to on-going land-use changes leading to habitat loss, the shortening of fallow periods, and over-grazing, diverse sites for juveniles are becoming fewer [48]. This development is more pronounced when the current adult populations are already under high human pressure (e.g. harvesting and pollarding), causing removal and vitality impairment of reproductive individuals. This can reduce the availability of seeds and may thereby lead to a lack of regeneration [49].

The results obtained by the spatial analysis show the interest of GIS as tool for sustainable management of natural resources [50].

3.4 Human Pressure in the Reserve

Several human activities were carried out in the Wildlife Reserve of Oti-Mandouri and constitute forms of pressure on the plant resources in this protected area. The main activities were illegal logging, carbonization, fishing, hunting, bush fires, violation of the area, pasture, fruits gathering, transhumance, tourist's visits, harvest of the straw and fibers and medicinal plants gathering (Fig. 7).

This protected area is constantly violated by the bordering populations, which have many pedestrian tracks allowing them either to join other villages or to go to their farms located beyond the reserve. The agricultural clearings are rare in this reserve. However, some agricultural installations were observed on the northwestern and south-eastern boundaries. The illegal wood cuttings are also frequent on the limits apart some cases of cuttings noted inside the reserve. It is the same observation for the clandestine pastures.

Fig. 7. Some human activities encountered in the protected area
A: Illegal wood harvesting; B: Stem bark withdrawal for medical purposes; C: Charcoal production and D: Grazing

As underlined by several authors in West Africa, all the categories of protected areas are affected by the anthropogenic activities [51,52]. Indeed, various activities are undertaken in the reserve by the bordering populations. These activities have significant negative impact on the integrity of the reserve and the conservation of its resources. The same activities was highlighted by [12,5,6] respectively in the protected area of Barkoissi (Togo), reserve of Alédjo (Togo) and in the wildlife reserve of Oti-Mandouri (Togo).

This study showed that the floristic species composition is different in protected savanna habitats versus unprotected savanna. The protected gallery forests on the other hand have a similar floristic composition as the unprotected gallery forest. This suggests that human disturbance affects savanna species composition more than gallery forest [29]. This is in accordance with the theory saying that gallery forests are refuge areas for many plants and animals in dry regions [53]. If species composition of gallery forests is not significantly modified by human disturbance, this may suggest low human pressure on gallery forests in the study area or may depend on the accessibility or disturbance threshold in this habitat [29].

The differences in species composition observed in this study between protected and unprotected savannas may be explained mostly by a combined effect of selective logging and cutting, and livestock grazing (see Fig. 7A and 7B). Surrounding unprotected savannas are highly subjected to these latter human disturbances. Mainly larger individuals of valuable tree species are selected for logging and cutting; and this involves modification of microclimate that leads to species composition change of these habitats. Moreover, it has been argued that human disturbance such as logging usually causes an immediate decline in biodiversity followed by a recovery not necessarily of the same species [54,55]. Some species may tolerate disturbance while others may disappear.

Among the anthropogenic disturbances observed in the field in this study, farming was the most common, followed by tree cutting and burning [56].

In this reserve, the harvesting of non-timber forests product (NTFP) is very crucial (see Fig. 7B). Many species such as *Khaya senegalensis, Sclerocarya birrea, Afzelia africana* and *Pterocarpus erinaceus* are heavy harvested by the indigenous people. *K. senegalensis, A. africana* and *P. erinaceus* are harvested by Fulani to feed their livestock and are one of the few sources of fodder in the dry season. This result is consistent with that of [45]. *K. senegalensis* and, *S. birrea* barks are harvested by local farmers and are used as an important medicine to treat various diseases including malaria, gastrointestinal diseases, and anemia [57]. This explains the strong pressure on the medicinal plant species in this reserve. In addition, these plants are highly prized for their timber. Removal of foliage and bark is expected to decrease individual growth and productivity. These activities lead to vegetation degradation and so, wildlife habitat destruction [5]. Trees cuttings were used either for energy purpose or for building and craft materials. In these rural areas, carbonization was realized using traditional techniques (see Fig. 7C). It constitutes, therefore, a serious threat for the woody resources of the reserve. The same observations were made in Alédjo protected forest in Togo [5].

4. CONCLUSION

This study shows that the Wildlife reserve of Oti-Mandouri has a high woody potential. It also revealed specific-habitat species composition change and specific-species population structure in relation to specific anthropogenic disturbance. Four vegetation types were identified, with an account of 116 woody species from 33 families and 84 genera. The study highlighted the principal activities undertaken in the reserve. Overall, our study demonstrates the complexity of the human land-use impact and contributes to the improved understanding of the land-use impact on savanna vegetation and diversity.

A large variation in the identified vegetation groups is observed, especially for the dendrometric parameters. Effective conservation strategies are needed for the species in the Wildlife reserve of Oti-Mandouri and should be designed based on the specificity of the identified vegetation groups.

Land-use and climatic changes may more strongly affect savanna vegetation and diversity patterns in future. Therefore, adaptable management and conservation strategies in the communal as well as in the protected areas are required to ensure the availability of natural resources for local people and to protect ecosystems and biodiversity in the long term. Management must be based on a solid scientific foundation and should be able to adapt to changing conditions. Controlling fuel wood collection and logging will be a key task involving preventive disturbance and restoration in unprotected savanna ecosystems. The promotion of rapid growth species planting for fuel use in unprotected areas should also be developed.

All these management recommendations, should be further discussed with all stakeholders for jointly developing feasible ways for ‘‘putting’’ them into practice. Hereby, learning from traditional ecological knowledge and management systems of local people will help to produce culturally and ecologically rational conservation and management strategies.

ACKNOWLEDGEMENTS

This work was supported by grants from the IRD, AIRD, AFD through RIPIECSA research program and the International Tropical Timber Organization (ITTO, Japan). The authors are very grateful to the editor and four anonymous reviewers for their constructive comments that greatly improved this paper. Special thanks go to our field assistants who helped us in data collection and to local populations for their hospitality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bruner AG, Gullison R, Rice RE, Da Fonseca GAB. Effectiveness of parks in protecting tropical biodiversity. Science. 2001;291:125-128.
2. Fandohan AB, Assogbadjo AE, Glèlè Kakaï RL, Sinsin B. Effectiveness of a protected areas network in the conservation of *Tamarindus indica* (Leguminosea-Caesalpinioideae) in Benin. Afr J Ecol. 2011;49:40-50.
3. Nacoulma BMI, Schumann K, Traoré S, Bernhardt-Römermann M, Hahn K, Wittig R et al. Impacts of land-use on West African savanna vegetation: A comparison between protected and communal area in Burkina Faso. Biodiv Cons. 2011;20:3341-3362.
4. N'guessan E, Dibi NH, Bellan M, Blasco F. Pression anthropique sur une réserve Forestière en côte d'ivoire : apport de la Télédétection. Télédétection. 2006;5:307-323. French.
5. Wala K, Woegan AY, Borozi W, Dourma M, Atato A, Batawila K et al. Assessment of vegetation structure and human impacts in the protected area of Alédjo (Togo). Afr J Ecol. 2012;50:355-366.

6. Dimobe K, Wala K, Batawila K, Dourma M, Woegan YA et al. Analyse spatiale des différentes formes de pressions anthropiques dans la réserve de faune de l'Oti-Mandouri (Togo). VertigO. 2012;14:1-22. French. Available: http://vertigo.revues.org/12423
7. Poorter L, Bongers F, Lemmens RHMJ. West African forests: introduction. In: Poorter L, Bongers F, Kouamé' FYN, Hawthorne WD, (Eds). Biodiversity of West African Forests, an Ecological Atlas of Woody Plant Species. Oxon and Cambridge UK and USA: CABI; 2004.
8. Adjonou K, Bellefontaine R, Kokou K. Woodlands of Oti-Keran National Park in northern Togo: structure, dynamics and impacts of recent climate changes. Sci Chang Map / Sech. 2009;20:394-396. French.
9. Ehui KS, Hertez WT, Preckez P. Forest resources depletion, soils dynamics and agricultural productivity in the tropics. J Environ Econ Manage. 1990;18:136–154.
10. Scoones I. Living with Uncertainty: New Directions in Pastoral Development in Africa. London: SRP, Exeter; 1995.
11. Glèlè Kakaï R, Sinsin B. Structural description of two Isoberlinia dominated communities in the Wari-Maro forest reserve (Benin). S Afr J Bot. 2009;75(1):43–51.
12. Folega F, Zhao XH, Zhang CY, Huang HG, Dimobe K, Pereki H, et al. Quick numerical assessment of plant communities and land use change of Oti prefecture protected areas (North Togo). Afr J Agric Res. 2012;7(6):1011-1022.
13. Lykke AM. Assessment of species composition change in savanna vegetation by means of woody plants' size class distributions and local information. Biodiv Cons. 1998;7:1261-1275.
14. Bellefontaine R, Gaston A, Petrucci Y. Management of natural forests of dry tropical zones. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy; 2000.
15. Wala K, Sinsin B, Guelly AK, Kokou K, Akpagana K. L'arbre et sa fonction chez les Nawdba de Doufèlgou (Togo). Ann Bot Afr Ouest. 2004;3:13-22. French.
16. Kokou K, Sokpon N. Les forêts sacrées du couloir du Dahomey. BFT. 2006;288:15-23. French.
17. Tchamie TTK, Bouraima M. Plant formations Soudou Dako-shelf in the chain Atacora and recent developments. J Bot Soc Bot France. 1997;3:83-97. French.
18. White F. The vegetation of Africa-related natural resources. Paris: Orstom-Unesco; 1986. French.
19. Ern H. Die vegetation Togo. Gliederrung, Gefährdung. Erhaltung Willdenowia. 1979;9:295–312.
20. IUCN/PACO. Evaluation of management effectiveness of protected areas: protected Togo [M] areas, IUCN, Burkina Faso. 2008 ;44. Available: http://www.papaco.org, 2008
21. Natta AK, Sinsin B, Van Der Maesen LJG. A phytosociological study of Riparian forests in Benin (West Africa). Belg J Bot. 2003;136:109–128.
22. Dourma M, Wala K, Bellefontaine R, Batawila K, Guelly K, Akpagana K. Comparison of the use of forest resources and regeneration between two types of clear Isoberlinia forests in Togo. BFT. 2009;302(4):5-19. French.
23. Westhoff V, Van Der Maarel E. The Braun-Blanquet approach, 2nd ed. In: Whittaker R.H. (ed.). Classification of plant communities. Junk, The Hague. 1978;287-399.
24. Bonou W, Glèlè Kakaï R, Assogbadjo AE, Fonton HN, Sinsin B. Characterisation of *Afzelia africana* Sm. habitat in the Lama forest reserve of Benin. For Ecol Manag. 2009;258(7):1084-1092.
25. McCunne B, Mefford MJ. Multivariate Analysis of Ecological Data Ver: 4. 14. MjM Software. Oregon, USA; 1999.

26. Magurran AE. Ecological Diversity and its Measurement. UK: Cambridge University Press; 1988.
27. Kent M, Coker P. Vegetation Description and Analysis: A Practical Approach. John Wiley & Sons, UK; 1992.
28. Philip MS. Measuring Trees and Forests. London: CABI; 2002.
29. Houehanou TD, Assogbadjo AE, Glèlè Kakaï R, Kyndt T, Houinato M, Sinsin B. How far a protected area contributes to conserve habitat species composition and population structure of endangered African tree species (Benin, West Africa). Ecological Complexity. 2013;13:60–68.
30. Husch B, Beers T, Kershaw J. Forest Mensuration. 4th ed. Ronald Press Company, London; 2003.
31. Newton PF, Lei Y, Zhang SY. Stand-level diameter distribution yield model for black spruce plantations. For Ecol Manag. 2005;209:181–192.
32. Johnson NL, Kotz S. Distributions in Statistics: Continuous Univariate Distributions. New York: John Wiley & Sons; 1970.
33. Caswell H. Matrix Population Models: Construction Analysis and Interpretation. 2nd ed. Sinauer Associates; 2001.
34. SAS Institute Inc, SAS Online Doc 9.1. SAS Institute Inc., Cary; 2004.
35. Folega F, Zhao XH, Zhang CY, Wala K, Akpagana K. Ecological and numerical analyses of plant communities of the most conserved protected area in North-Togo. Int J Biodivers. 2010;2(11):359-369.
36. Woegan YA. Diversity of woody vegetation of the National Park Fazao-Malfakassa and wildlife reserve of Alédjo (Togo). PhD dissertation, Lomé, Togo; 2007. French.
37. Wala K 2004. Vegetation Atakora Benin: Floristic diversity and human impact phytosociologie. PhD dissertation, Lomé, Togo; 2004. French.
38. Aubréville A. Flore forestière soudano-guinéenne: AOF – Cameroun – AEF. Paris: Geographical Publishing Company, Maritime and Colonial; 1950. French.
39. Pare S, Savadogo P, Tigabu M, Oden P, Ouadba J. Regeneration and spatial distribution of seedling populations in Sudanian dry forests in relation to conservation status and human pressure. Trop Ecol. 2009;50:339-353.
40. Houehanou TD, Glèlè Kakaï RL, Assogbadjo AE, Kindomihou V, Houinato M, Wittig R, Sinsin BA. Change in the woody floristic composition, diversity and structure from protected to unprotected savannahs in Pendjari Biosphere Reserve (Benin, West Africa). Afr J Ecol. 2012;51:358–365.
41. Ouédraogo A. Diversity and dynamics of woody vegetation in the eastern part of Burkina Faso. PhD dissertation, Ouagadougou, Burkina Faso; 2006. French.
42. Atakpama W, Dourma M, Wala K, Péréki H, Batawila K and Akpagana K. Structure and Natural Regeneration of *Sterculia setigera* Del. Plants Communities in Sudanian Zone of Togo (West Africa). IJPSS. 2014;3(4):330-346.
43. Okomo C. Study of the impacts of human activities on the diversity of flora and provinces Zoundwéogo Nahouri (Burkina Faso). Master Degree, Polytech Univ Bobo-Dioulasso, Burkina-Faso; 2002. French.
44. Bhuyan P, Khan ML, Tripathi RS. Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas, India. Biodiv Cons. 2003;12:1753–1773.
45. Gaoue OG, Ticktin T. Patterns of harvesting foliage and bark from the multipurpose tree *Khaya senegalensis* in Benin: variation across ecological regions and its impacts on population structure. Biol Conserv. 2007;137:424–436.
46. Schumann K, Wittig R, Thiombiano A, Becker U, Hahn K. Impact of land use type and bark- and leaf-harvesting on population structure and fruit production of the baobab

tree (*Adansonia digitata* L.) in a semi-arid savanna, West Africa. For Ecol Manag. 2010;260:2035–2044.
47. Condit R, Sukumar R, Hubbell SP, Foster RB. Prediction population trends from size distributions: A direct test in a tropical tree community. Am Nat. 1998;152:495–509.
48. Jurisch K, Hahn K, Wittig R, Bernhardt-Römermann M. Land-use impact on the growth and survival of seedlings and saplings in West African savannas. J Veg Sci. 2013;24:101–112.
49. Makana JR, Thomas SC. Impacts of selective logging and agricultural clearing on forest structure, floristic composition and diversity and timber tree regeneration in the Ituri Forest, Democratic Republic of Congo. Biodiv Cons. 2006;15:1375–1397.
50. Tiwari AK, Kudrat M, Manchanda ML. Remote sensing and GIS: Indispensable tools for regional ecological studies. J Trop Ecol. 1996;37:79–92.
51. Pereki H, Wala K, Thiel-Clemen T, Balinga Bessike MP, Zida M, Dourma M, Batawila K, Akpagana K. Woody species diversity and important value indices in dense dry forests in Abdoulaye Wildlife Reserve (Togo, West Africa). Int J Biodivers. 2013;5(6):358-366.
52. Adjonou K, Djiwa O, Kombate Y, Kokutse AD, Kokou K. Study of spatial dynamics and structure of dense dry forests relics of Togo: Implications for sustainable management of protected areas. Int J Biol Sci. 2010;4(1):168-183. French.
53. Porembski S. Phytodiversity and structure of the Comoé River Gallery forest (NE Ivory-Coast). Life forms and dynamics in Tropical Forests. Diss Bot. 2001;346:1–10.
54. Noble IR, Dirzo R. Forests as human-dominated ecosystems. Science. 1997;277:522–525.
55. Sagar R, Raghubanshi AS, Singh JS. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. For Ecol Manag. 2003;186:61–71.
56. Folega F, Zhang CY, Samake G, Wala K, Batawila K, Zhao XH, Akapagana K. Evaluation of agroforestry species in potential fallows of areas gazetted as protected areas in north-Togo. Afr J Agric Res. 2011;6(12):2828-2834.
57. Arbonnier M. Trees, shrubs and lianas of dryland Africa West CIRAD, France; 2000. French.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=497&id=32&aid=4356