International Journal of Biodiversity and Conservation Vol. 2(11), pp. 359-369, November, 2010
Available online http://www.academicjournals.org/ijbc
ISSN 2141-243X ©2010 Academic Journals

Full Length Research Paper

Ecological and numerical analyses of plant communities of the most conserved protected area in North-Togo

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Accepted 13 September, 2010.

The 36 statements obtained from sampling investigation in Galangashi protected areas (Northern Togo) were subjected to floristic processing and several multivariate analyses to study the overall plant diversity, to determine the distribution of life form and phytogeographic type; to identify and describe the main plant communities' and the ligneous structure of these plant communities. Detrended correspondence analysis (DCA) and hierarchical clustering was used for ordination and classification of samples to determine the plant groupings. The plant community was defined by indicator value such as fidelity and abundance. The results showed that four plant communities were discriminated from 36 statements. The statements were well distributed in the factorial plan form by axe 1 and 3 of DCA. The plant communities were distributed along the moisture gradient in the DCA ordination. The Sudano-Zambesian species followed by Sudanian species were the phytogeographic types most found. Moreover, micro-phanerophytes were the most represented life form. The diversity indices in both plant communities are well significant and indicate a good distribution of species in the area. In overall, the vegetation condition of the protected area is somehow disturbed while most of the plant communities are stable. These results confirmed the assertion that Galangashi ecosystem still presents a typology of less disturbed area.

Key words: Diversity, DCA, Galangashi, phytogeographiy, plant community

INTRODUCTION

The growing interest of policy makers in the conservation and protection of natural resources has led them to take legal laws in favor of biodiversity. These provisions encourage or strengthen existing laws on the creation of protected areas. At current note, most countries in the world, especially in Africa, have created or maintained protected areas inherited from colonization (IUCN, 1994). In Togo, some protected areas saw their limits expanded to protect more diversity in 1971 (Tchamie, 1994). Although it presented from north to south, a variability of ecosystems, Togo is not a country known for its protected areas (IUCN, 2009). This failure is due to the fact that these ecosystems are managed and administered not on the basis of scientific data (Woegan, 2007). For instance, out of the 43 ecosystems selected in the context of consensual rehabilitation project of protected areas, only a few of them like Aboudoulaye Wildlife Reserve, Classified Forest of Tchorogo, National Park of Fazao-Malfakassa, Alédjo Wildlife Reserve and the Oti-Mandouri Wildlife Reserve were subjected to preliminary phytoecological studies (DFC, 2003; Atato, 2002; Woegan, 2007; Dimombe, 2009).

With economic recovery and the will of Togolese authorities to reinvigorate the tourism sector, the sustainable management of protected areas is the priority these days. However, no such management is possible if the primary data of the resources present in these ecosystems are not available on the flora, fauna, biological communities and their demographic structure and the forms of disturbances especially from the

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bordering populations. This is necessary and fundamental for the constitution of a database in this great project of rehabilitation and management of protected ecosystems.

The forest of Galangashi still has the features of the least disturbed natural formations. But it is not spared by strong pressures on behalf of bordering populations. It is therefore imperative to conduct investigations *in situ* to collect floristic and environmental data. This article is a contribution and aims to synthesize floristic composition of the major plant groupings as well as to determine and compare the living condition of each group to those of other protected areas in Togo and in neighboring countries.

Survey area

The study area covered the protected area of Galangashi. This ecosystem of an area of 7500 ha was classified as wildlife reserve by Decree No. 865 of 14-09-1954 and then requalified as a classified forest by Order No. 006/MERF / case of 02-02-2005. The boundaries of the survey area were those of the year of its first demarcation (Sournia et al., 1998). Galangashi Reserve is situated in eco - floristic zone 1 or northern plain (ERN, 1979). Administratively it is located in Oti District (Figure 1). It lies between longitudes 0°15' and 0°23' and latitudes 10°19' and 10°32'.

The relief of the study area is flat with an average altitude around 150 m. It is also a part of the vast plain of Oti. The region is dominated by leached ferruginous tropical soils, hydromorphic, with sandstone colluviums and hydromorphic minerals (Lamouroux, 1969). Moreover, it is drained by the seasonal rivers such as Gambara Koukombou.

The region has a Sudanese tropical climate or semi sahelian climate marked by the alternation of a long dry season with a short rainy season (Yéma et al., 1981). The first season is extended from November to May, while the latter extends from June to October. A heavy rainfall used to be recorded in August, but in recent decades there has been a sharp decrease in precipitation that rotates around 1058.9 mm/year (Moussa, 2008). Temperatures vary between 20 and 35°C with an annual average of 28.5°C for the station Mango (Figure 2) (Moussa, 2008).

The major floristic features of the reserve consist of a few riparian forests, dry forests, wooded savannas, shrub savannas, grasslands and flooded savannas. The most common fauna species, noted during the investigation are: Bovidae, the Cercopithecidae. The avifauna is mainly composed of wild guinea fowl, Turtledoves.

The region has a strong anthropogenic influence on vegetation. The population of Oti District, located in the bulk of the investigation zone, had 126,000 inhabitants in 2000 that increased to 135,000 in 2006. The ethnic groups living in the study area includes Moba, Tchokossi, Mossi and Fulani. The major human activities are agriculture, firewood collection and initiation of bush fires during the dry season. The main crop species are sorghum, millet, groundnuts, cowpeas, maize and yams while livestock include poultries, caprine and sheep.

MATERIALS AND METHODS

Choice of transect

The transect method has been coupled with that of the sampling technique by the statements. The orientation and location of transects were defined through the results of an unsupervised classification of Landsat ETM + satellite image of the 2000s. This classification has been achieved from the algorithm of ISODATA (Interactive Self-Organizing Data Analysis Algorithm Technology) (Tou and Gonzalez, 1974). The classification allowed land having a synoptic view of different spectral signatures and deducing the nature of the cover and usage. A total of 5 transects from 5 to 10 km were selected and traced.

Phytosociological concept

The adopted sampling technique is based on the phytosociological concept of Braun-Blanquet (Westhoff and van der Maarel, 1978). The floristic statements of 30×30 m were placed at every 100 m along the previously defined transects. The selection of 900 m^2 as minimum plot area is justified by the fact that they have been successfully used in Togo in the past and in the sub region during various research works within the tropical Sudano-Guinean region (Dourma, 2008; Woegan, 2007; Wala, 2004). In total, 36 statements with 30×30 m size were installed.

The species were indentified following Hutchinson and Dalziel (1954 - 1972), and all trees with DBH ≥ 10 cm were recorded. All species were assigned a coefficient of abundance / dominance (R = one individual, + = insignificant recovery, 1 = less than 5%, 2 = 5-25%, 3 = 25-50%, 4 = 50-75%, 5 = more than 75%), as suggested by Braun-Blanquet (Westhoff and van der Maarel, 1978).

For qualitative ecological characterization, edaphic variables (structure and texture of the soil), topographic attributes (plateau, slope, versant, valley and bank) and disturbance levels (fire, cutting and pasture) were recorded along with the geographic coordinates. Climatological data (rainfall, temperature and humidity) for any period were obtained from databases of meteorological stations closer to the study areas.

Data processing

After digital processing of the 36 samples, the general list of species composing the floral procession has been established. On the basis of reference documents such as Aké Assi (1984) and Guinko (1984), these species have been classified according to their phytogeographical types, while their life form classification was based on Raunkier's (1934) definition. For each sample indices of diversity: species richness, Shannon index (1948), Pielou's evenness (1975) and Jaccard similarity (1901) was calculated to deduce information about the distribution of species. The following formulae were used to calculate these indices.

Shannon diversity index (H'):

$$H' = -\sum_{i=1}^{s} (Ni / N) \times \log_2 (Ni / N)$$

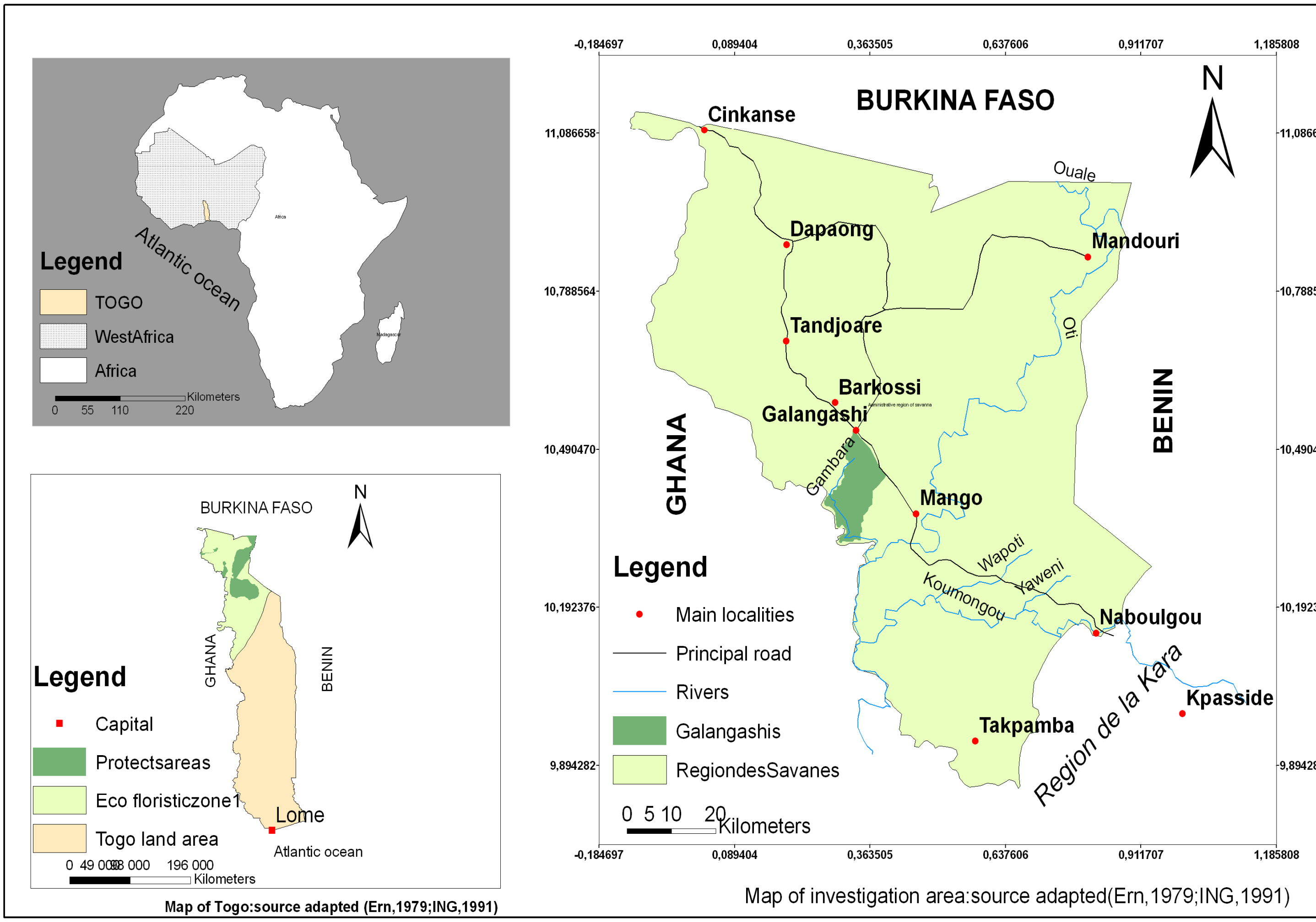

Figure 1. Location of survey areas.

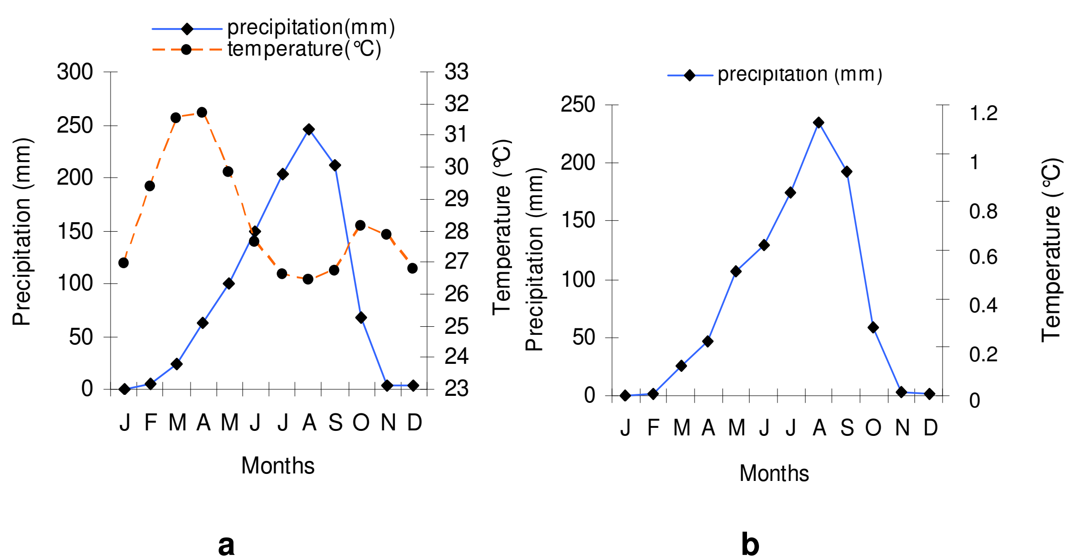

Figure 2. The mean monthly temperature and monthly precipitation of two localities around the study areas (a: Mango locality; b: Barkossi locality).

Pielou's evenness index (E):

$$E = \frac{H'}{H'\max} = -\frac{\sum_{i=1}^{s}(Ni/N)\times\log_2(Ni/N)}{\log_2(s)}$$

Where Ni is the number of relevés in which the species i is present; N is total number of relevés, and S is the number of species.

Jaccard similarity index (J):

$$J = 100 \times \frac{c}{a+b-c}$$

Where a is the number of species in community A, b is number of species in community B, while c is the number of species common to both communities.

Finally a matrix of (36 statements × species) was subjected to three multivariate analyses. The first analysis was an ordination of the samples in indirect gradient: DCA (Detrended Correspondence Analysis, Hill, 1979b) to extract the plant communities and to deduce environmental factors greatly influencing plant distribution. Out of the DCA, three groups discriminated, the G2 group was found consisting mostly of shrublands and woody savannas and was subjected to hierarchical classification (clustering) by the method of Ward (1963) from the Euclidean distance. In this second analysis, two sub groups were obtained.

The species characterizing the groups of statements formed from DCA and clustering were determined on the basis of INDVAL or indicator value method (Legendre and Legendre, 1998).

This analysis was preferred to TWINSPAN (Two Indicator Species Analysis) of Hill (1979a) for the fact that indicator species can be deduced from a hierarchical clustering or non-hierarchical clustering with indicator values being the product of species fidelity and their abundance, compared to the other species of their community. The data processing and analysis were done using SPSS, CAP ® 2.15 (Community Analysis Package) and CANOCO ® 4.5.

RESULTS

Floristic analysis

133 plant species were identified after data analysis from the floristic inventory. These species which are grouped into 45 families and 104 genera, corresponds to 3.22% of flora of Togo. The representative families with at least 5 species were: Fabaceae, Poaceae, Combretaceae, Rubiaceae, Euphorbiaceae, Mimosaceae and Caesalpiniaceae (Figure 3). *Andropogon tectorum*, *Terminalia laxiflora* and *Sclerocarya birrea* were the most common species (Figure 4).

The Sudano-Zambesian (SZ) and Sudanian (S) species were the most recorded representatives on phytogeographical level and corresponded respectively to 32 and 16 species (Figure 5). They were followed by Guineo-Congolian (GC), Pantropical (Pan) and Sudano-Guinean (SG) elements which showed an equal distribution (14 species). The species related to the Sudanese area correspond to 46.52% of the identified species. The phanerophytes entirely dominated the biological spectrum with 68 species (Figure 6). The other life form types had a number of species which ranged between 15 and 7 except for a single parasite.

Within phanerophytes (Figure 7), microphanerophytes (27 species) are followed nanophanerophytes (22 species) and mesophanerophytes (19 species).

Plant communities

The technique of ordination and hierarchical classification allowed the discrimination of four plant communities (Figures 8 and 9). The statistical summary of the DCA is recorded in Table 1. The four axes of the DCA have expressed a total variance of 20.2%. A unimodal distribution of samples is noted and was well confirmed by the standard deviation of the axis 1 which is greater than 4. The factorial plane formed by the Axis 1 and 3 is significant. It allowed to identify sharply the groupings G1 and G3 of the heterogeneous grouping G2. The similarity indices (Table 2) infer from the Jaccard method has shown that the grouping G1 present values which decreases compared to the other three.

From this analysis, the major environmental gradient which influences the distribution of species remains the soil moisture. Axis 1 of the DCA opposes on left a formation on less wet soils to hydromorphic and flooded soils on the right.

The four groupings appear as follows:

1. The Grouping of *Anogeissus leiocarpus* (DC) Guill. And Perril and *Cissus populnea* Guill. and Perril (G1) is found in dry dense forests. It grows on poorly evolved grounds with some hydromorphic colluvial. G1 occurs along the drainage axes and at the bottom of slopes. 77 species are encountered in this grouping; by cons the Shannon index and Pielou regularity are, respectively, equal 5.91 and 0.94 bits. The trees represent 21.33% of the species abundance of G1, shrubs 32.33%, herbs and lianas 46.66%. However, lianas represent only19.78%.
2. The Grouping of *Andropogon tectorum* Schumach. And Thonn. and *Crotalaria graminicola* Taub. Ex Baker (G2a) is dominant in shrubby savanna. Herbaceous taxa represent 46.87% of the total abundance of species whereas shrubs and trees represent 37.50 and 15.62% respectively. This grouping records 75 species. The index of Shannon and Pielou are respectively 5.65 bits and 0.90. It develops on sandy-clayey substrate.
3. Grouping of *A. tectorum* Schumach. and Thonn and *Combretum molle* R.Br. ex G. Don. (G2b) is dominant in wooded savanna. It evolved on ferruginous tropical hydromorphic grounds. G2b contains 68 species; its Shannon diversity index and Pielou evenness are respectively, 5.60 bits and 0.92. The trees represent 21%

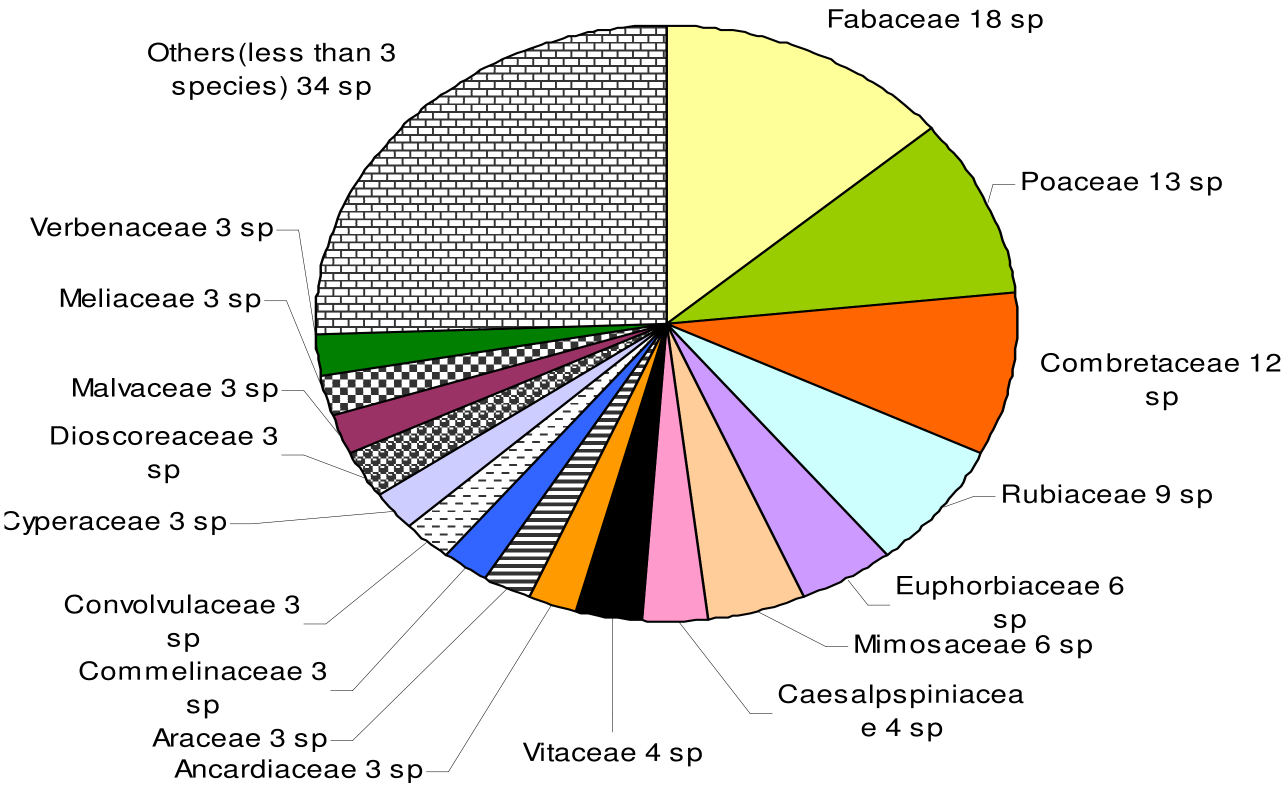

Figure 3. Specific spectra of families.

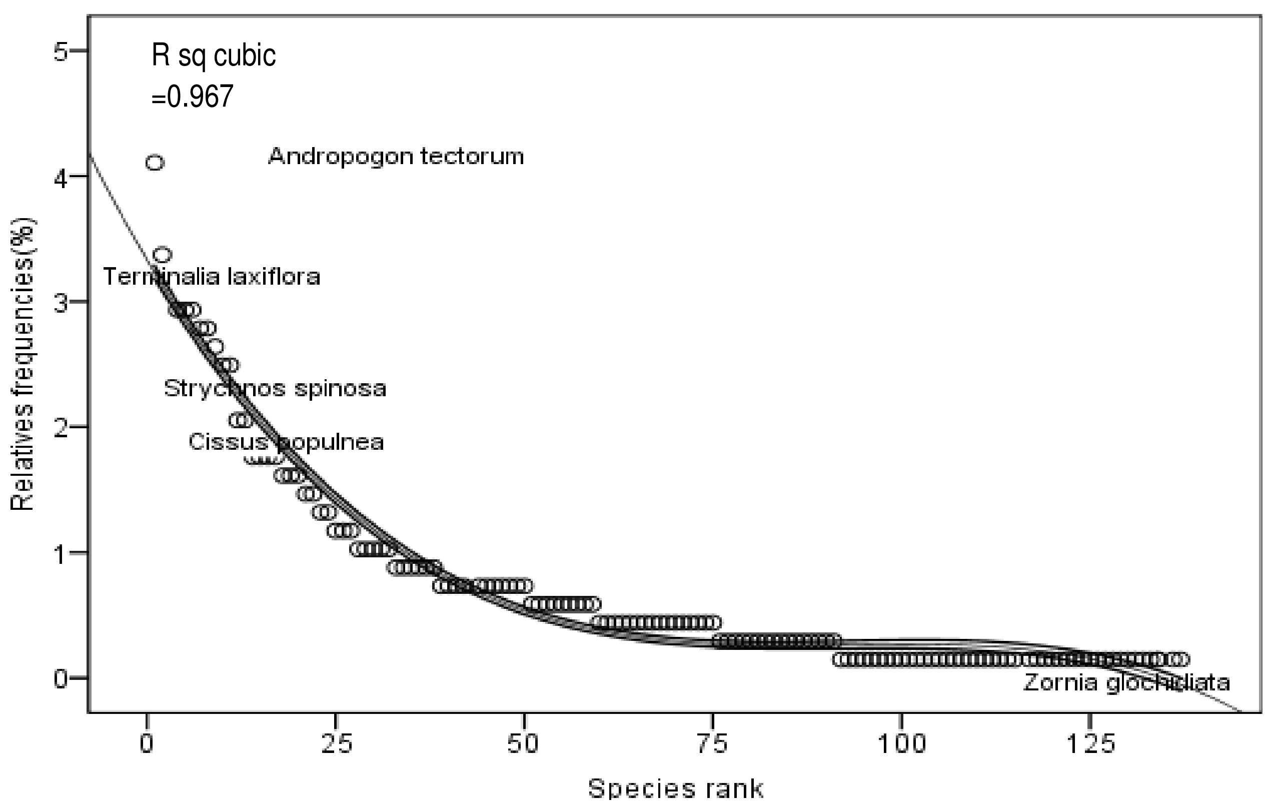

Figure 4. Curve rank - frequency of the ligneous species.

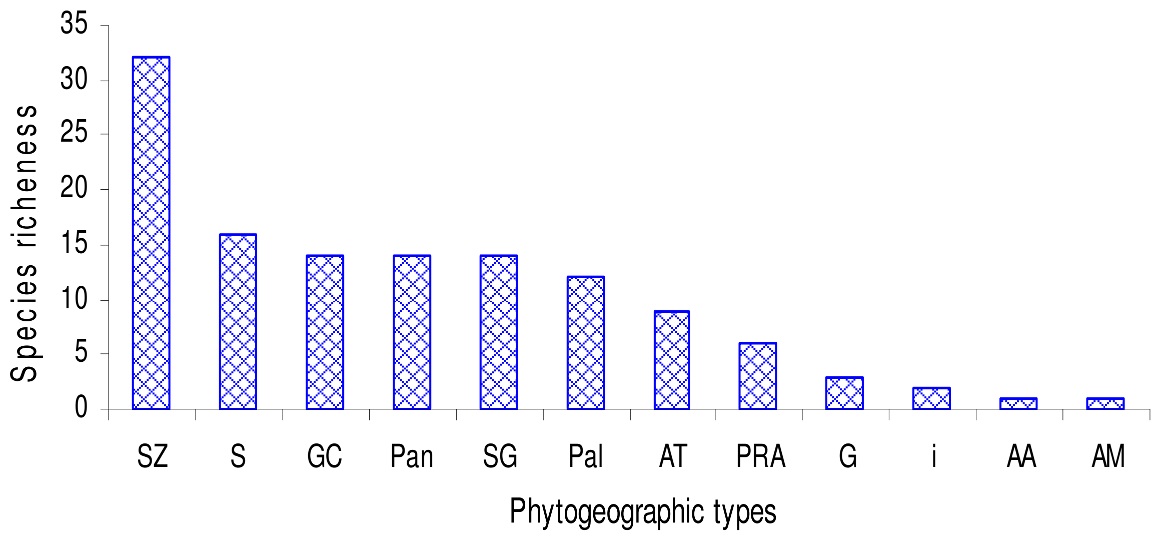

Figure 5. Overall frequency distribution of phytogeographic types (SZ: Sudano-Zambesian; S: Sudanian; GC: Guineo-Congolian; Pan: Pantropical; SG: Sudano-Guinean; Pal: Paleo-Tropical; AT: Afro-Tropical; PRA: Pluri Regional in Africa; G: Guinean; i: undetermined; AA: Afro –American, and AM: Afro-Malgash).

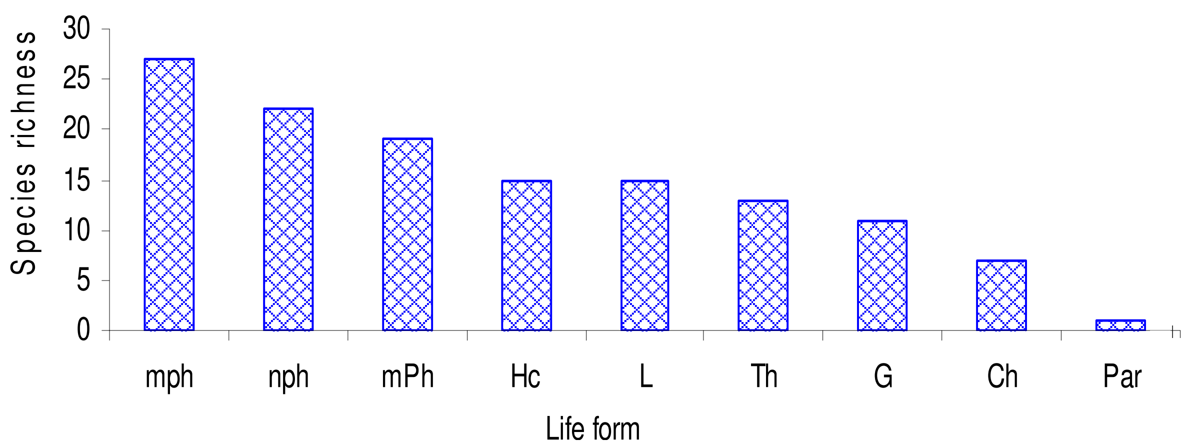

Figure 6. Frequency distribution of life forms. (Ph: Phanerophytes; Hc: Hemicryptophytes; L: Lianas; Th: Therophytes; G: Geophytes; Ch: Chamephytes, and Par: Parasites).

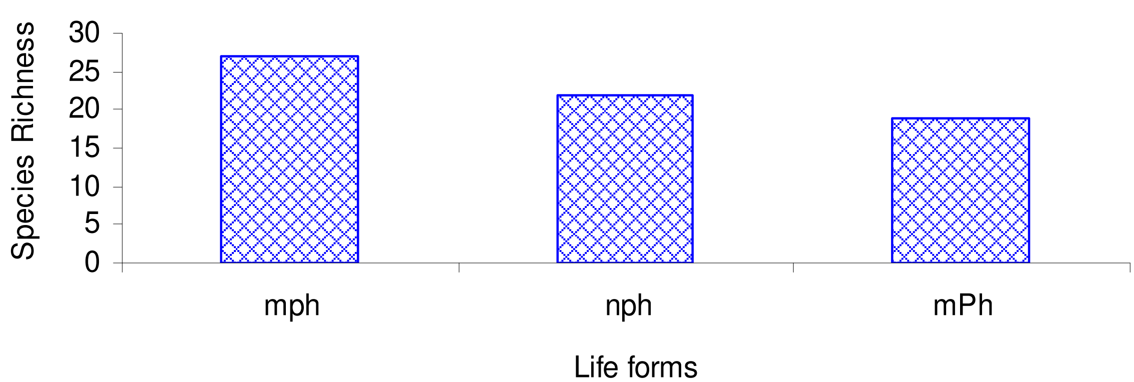

Figure 7. Frequency distribution of life forms (mph: Micro-phanerophytes; nph: Nano-phanerophytes, and mPh: Meso-phanerophytes).

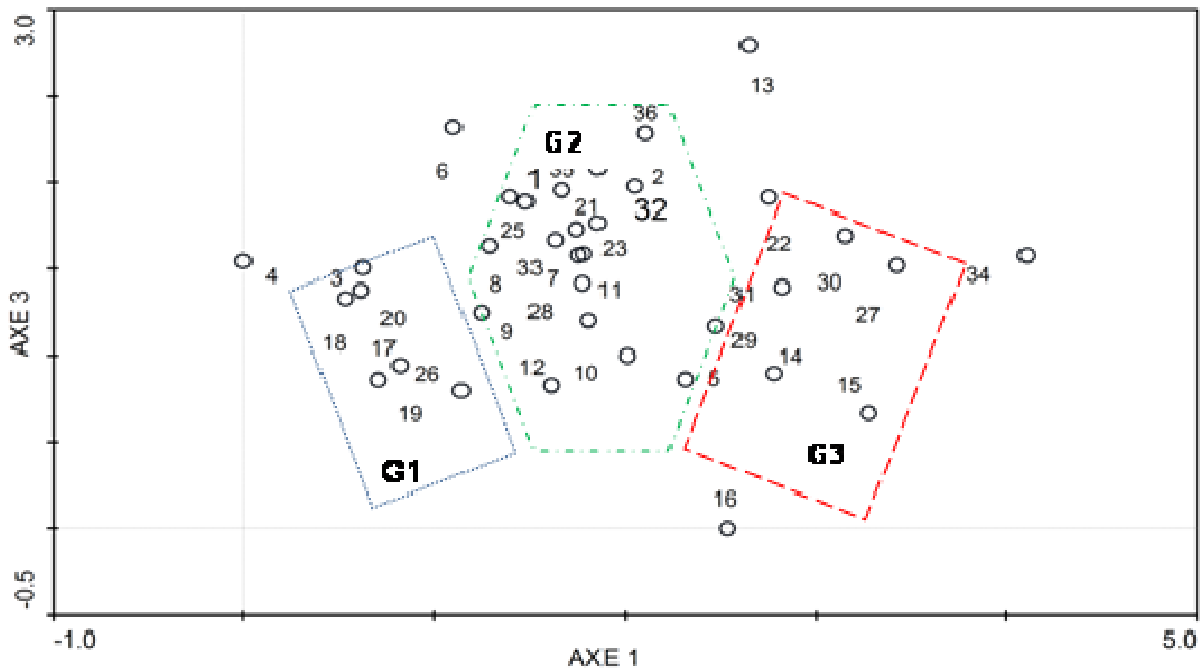

Figure 8. DCA ordination of 36 statements (G1: dry dense forest, G2: mosaic of woody savanna and shrubby savanna, G3: woody flooded savanna).

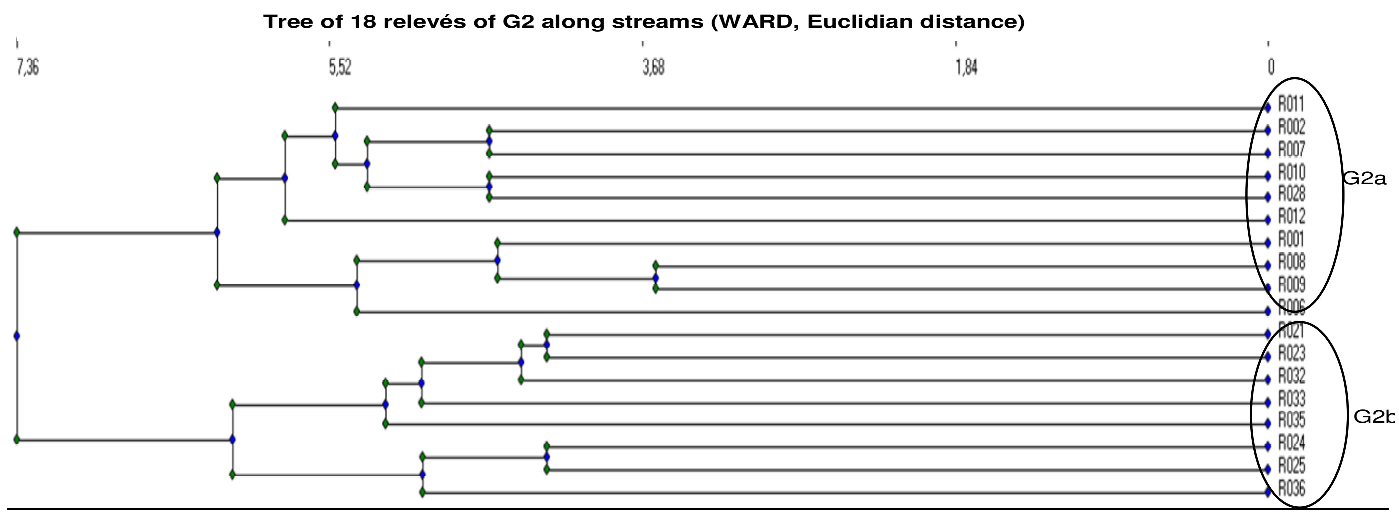

Figure 9. Dendrogram of 18 statements of G2 area showing two plant communities (G2a: Shrubby savanna; G2b: Woody savanna).

while the shrubs and herbs represent successively 38.81 and 40.18% of the total species abundance.

4. Grouping of *T. laxiflora* Engler and Diels. and *A. tectorum* Schumach. and Thonn (G3) is seen predominantly in flooded savanna. It grows on hydromorphic tropical ferruginous clay-sandy or clayey soil. This group has a specific richness (S) of 51 species. The Shannon diversity index and the regularity of Piélou are respectively equal to 5.27 bits and 0.92. The trees, the shrubs and the herbaceous plants correspond respectively to 17.28, 36.41 and 46.29% of the species total abundance in G3.

Diameter structure

The histograms (Figure 10) show the diametric structure ligneous in the four groups. The groups G2a, G2b and

Table 1. Statistical synthesis of ordination in indirect gradient of the 36 statements.

Axes	1	2	3	4	Total inertia
Eigen values	0.458	0.348	0.251	0.196	6.215
Lengths of gradient	4.106	3.707	2.789	2.993	
Cumulative percentage variance of species data	7.4	13.0	17.0	20.2	

Table 2. The similarity analysis of the four plant communities.

Species	G1	G2a	G2b	G3
G1				
G2a	45.19			
G2b	39.81	48.96		
G3	24.04	36.17	35.96	

G3 present relative high numbers of individuals within the lower diameter classes which decreases gradually following the high diameter classes. The high proportion of young individuals suggests a dynamic balance in the natural regeneration of these groups. This structure in <L> is proof of stability and a constant regeneration in the time. The G1 shows a structure in saw-tooth characterizing irregular distribution of diameter classes. This reflects a low regeneration capacity. The distributions of individuals by diameter classes are assimilated to a logarithmic function for G2a, G2b and G3 and polynomial of order 5 for G1.

DISCUSSION

The 133 species recorded represent 45 families and 104 genera of which 23.33 and 76.69% belong to monocotyledons and dicotyledons respectively. The species of this ecosystem, that would represent 3.22% of Togo flora species, are less than those identified in the protected areas of Alédjo (446 species) and Fazao-Malfakassa (479 species). This difference may be related to climatic determinism which is more humid and favorable in central Togo where these two ecosystems are located. However, according to Dimombe (2009) the 116 species listed in the wildlife reserve of Oti-Mandouri is slightly lower, even when compared with that of Galangashi, in the Sudanian climatic zone, with which it has the same surfaces.

The predominance of Combretaceae, Rubiaceae and Mimosaceae in the reserve indicated the conditions of a tropical Sudanian climate and the existence of forest ecological conditions (Gondard, 1964; Wala, 2004; Aubreville, 1950). The herbaceous species occupy an important place; this situation indicates sparsed vegetation and crossed by fires, humans and herds (Kokou and Guy, 2000).

The species SZ (24%) and S (12%) correspond to the major phytogeographical types of the reserve. The same tendency is observed in the reserve of Oti-Mandouri and in the forest of Niangoloko in Burkina Faso (Dimombe, 2009; Ouoba, 2006). In significant part of GC and SG, 21% show a forest affinity in the area. With 51% of phanerophytes (mph, mPh and nph) are considered as the dominant life forms in the landscape. The same situation occurs in Oti-Mandouri protected area in exception of the three main types of phanerophytes, recording 5% megaphanerophytes (Dimombe, 2009). The dominance of phanerophytes (57.89%) is also observed in the ecological and cultural site of Koro in Burkina Faso (Kadeba, 2009). This site, however, had a slightly lower rate of parasites (0.52%) compared to that of Galangashi (0.75%). These similarities were due to the fact that these ecosystems are almost found in the same climatic zone. The moisture and edaphic factors would appear as the major gradients along which the flora is distributed. Human activities in a meaningful measure also would be influenced by this distribution. The soil moisture was identified as the main gradient in the Oti-Mandouri wildlife Reserve, Alédjo and Fazao-Malfakassa and on the chain of Atakora Benin where DCA was used for statements ordination (Dimombe, 2009; Woegan, 2007; Wala, 2004).

The four described grouping are also met in Togo and in the sub region but in different conditions. *A. leiocarpus* dense dry forests were identified in the National Park of Fazao-Malfakassa where they also evolved on sandy-clayey substrates with low slopes (Woegan, 2007). Studies by Traore (1997) and Ouoba (2006) identified similar plant formation in the eastern part of Senegal and Burkina Faso where they grow on muddy –sandy- clayey soil and is found at the bottom of slopes.

The tree and shrub savanna dominated by *A. tectorum* do not have counterparts known in a close environment. Nonetheless, the groupings in Benin found *A. tectorum*

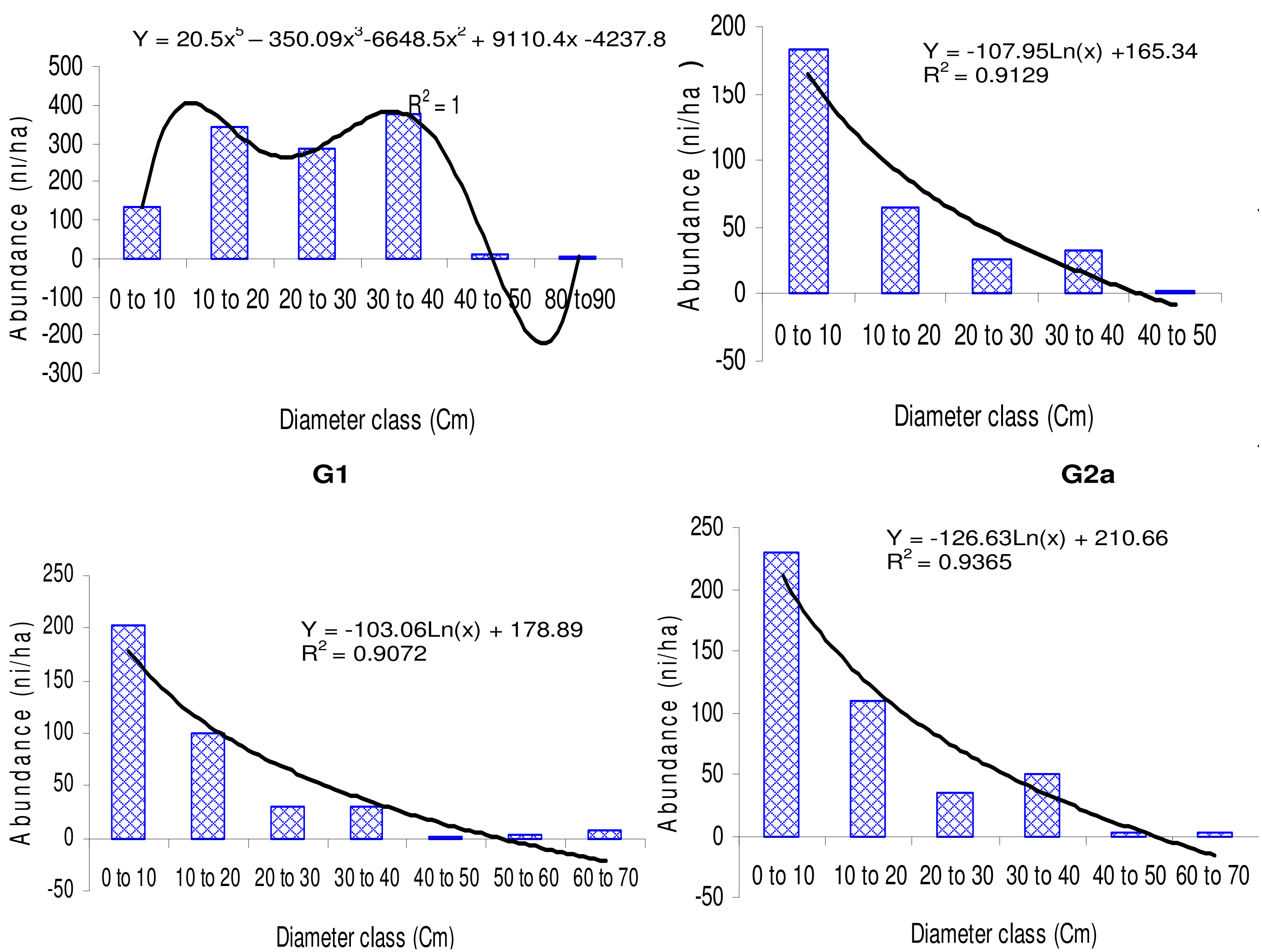

Figure 10. Diameter structure of the overall plant community.

as the second indicator species (Tente and Sinsin, 2006). These groupings evolved on rock chaos and at bottoms of the slopes.

The grouping of *T. laxiflora* is mentioned in the ecological and cultural site of Koro and in the classified forest of Niangoloko (Kadeba, 2009; Ouoba, 2006). The latter develop on hydromorphic grounds where it is noted to have temporary water retention, by cons those identified in the septentrional part of the chain of Atakora are developed on the slopes and summits (Wala, 2004).

Two distributions of the diameters classes were observed. The distribution in tooth of saws of *A. leiocarpus* dry dense forest showed low density in the first diameter class. This reflects a problem of species regeneration in this plant community. Grouping with a density of 430 feet.ha^{-1} is less dense than those studied in Cote d'ivoire (1236 - 2884 feet. ha^{-1} and in Benin 120-500 feet. ha^{-1} (Devineau, 1984; Biaou and Sokpon, 2003). By cons its basal area (37.72 m^2.ha^{-1}) is higher than the one studied by Biaou and Sokpon (17 m^{2}ha^{-1}) and lower to that described by Devineau (34 to 38 m^{2}ha^{-1}).

As far as studies by Rollet (1974) and Wala (2004) are concerned, plant groupings G2a, G2b and G3 show natural features through the decreasing distribution of diameter classes. Furthermore, according to Swaine et al. (1987), Wala (2004) and Dourma (2008), this distribution suggests a stability of these groups because of their great juveniles potential. The basal areas which are 5.01, 7.37 and 11.10 m^2/ha respectively, for G2a, G2b and G3 are much lower than that of G1.

Conclusion

The phytosociology of the Galangashi protected area presents four major groupings. These groupings varyfrom one to the other, but present strongly similar indices of diversities and good distribution of their species. The phytogeographical types of this area are in concordance with the prevalent climatic type. The presence of the lianas is a considerable indicator of closed vegetation by place, though the high rate of the species in the low layer indicates the existence of the disturbance factors from anthropogenic origin. The plant formation shows stability in their dynamics. Regarding the presence of such quite multiple pressures on behalf of humans on the phytocenose, and knowing the existing plant resources, it is thus imperative to rethink the technical management of this ecosystem by creating or strengthening a framework of dialogue where all stakeholders have their place.

ACKNOWLEDGEMENTS

The research was supported by Chinese and Togolese government under the direction of the Beijing Forestry University and Université de Lomé. We gratefully acknowledge the Ministry of Natural Resources of Togo for their technical assistance during the field work.

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