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Tree's spatial pattern, diversity and distribution in sub humid mountains ecosystems in south-west Togo

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West African Guinean forests are among the most diverse and threatened ecosystems in the world. The study aims to provide new insights about tree species patterns, abundance, and diversity for better management in Togo. Species diversity and density of trees were assessed in 170 plots randomly selected in the study area. Each tree with DBH >10 cm was identified and measured. Stem density, basal area, and diversity indices were calculated. In total, 243 species belonging to 170 genera and 44 families were identified in the study area. Five floristic groups were recognized. They are characterized respectively by *Lophira lanceolata, Pterocarpus erinaceus* and *Daniellia oliveri* association in Group 1*; Theobroma cacao, Elaeis guineensis* and *Morinda lucida* association in Group 2*; Elaeis guineensis, Persea Americana* and *Albizia zygia* association in Group 3; *Cola gigantea, Senna siamea* and *Erythrophleum suaveolens* association in Group 4 and *Pycnanthus angolensis, Ceiba pentandra* and *Pseudospondias microcarpa* association in Group 5. The Fabaceae, Moraceae and Malvaceae are the most represented families in the study area. The highest tree species diversity was observed in Group 4 (2.05 ± 0.61) and the lowest diversity in Group 2 (1.19 ± 0.64). Mean tree density ranges from 408.96± 202.17 (Group 1) to 273.90 ± 193.19 (Group 4). The highest tree basal area (27.99 ± 25.58 m^2/ha) is obtained in Group 3 and the lowest (15.84 ± 13.44 m^2/ha) is in Group 4. The presence of pioneer species in the study areas proves that the habitat has undergone serious anthropogenic disturbance events, which contribute to species loss.

Key words: Diversity, sub humid mountains ecosystems, Togo, richness, tree species, disturbance factors.

INTRODUCTION

Many factors have been attributed to tree species lost in tropical forests, it is believed to be generally driven by a complex interplay of various forces. These factors vary from demographic changes, poverty, policy responses of countries to ecological (such as fires), anthropogenic disturbances (such as logging, agricultural expansion) and climate change (Kolb and Diekmann 2004; Novick et al., 2003).

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The damaging consequences of biodiversity reduction include the loss of ecological services (such as biodiversity and watershed protection), the loss of many goods(such as timber and non-timber forest products),and the loss of means of existence for forest communities (ITTO, 2002). Repeated forest destruction, has resulted in the elimination of indigenous species and the development of degraded landscapes dominated by invasive species (Powell et al.,2011). Therefore, the possibility of species composition changing from species with hard wood to species with softer wood is created (Ter Steege, 2003). Native species populations generally decline in human-impacted habitats while exotic species often benefit (Jesse et al., 2018).

In many cases, natural recovery is unlikely because the degraded site has become subject to recurrent disturbances such as fire or grazing (Lamb et al.,2005). These disturbances are known to increase the vulnerability of forest species through micro-environmental changes that drastically influence the composition of forest understory (Appiah, 2013). Disturbances associated with anthropogenic activities have overruled natural disturbances in many tropical landscapes. If the human induced disturbance starts in a system, the degradation will continue until or unless some protective measures are introduced (Anitha et al., 2009).

Togo sub-humid mountainous zone is the domain of dense semi deciduous forests and Guinean savannas, now very degraded and disappearing (Ern, 1979). This domain is an integral part of the rainforests of west Africa, one of the world's hotspots of biodiversity and are referred as the Upper Guinean forests (Myers et al., 2000). The present vegetation is seriously under threat with considerable loss of tree cover. The area in Togo is called the ecological zone IV and is one of the places where habitat fragmentation and forest degradation are highly perceptible due to the development of cash crops (coffee, cocoa, cotton, etc.) which led to a conversion of forests into coffee and cocoa plantations (Adjossou, 2009). The remaining forests of the sub humid mountainous zone today is highly fragmented and is practically limited to forest buffers in hard-to-access area (Adjossou, 2009). This fact highlights a first research question: what are the current spatial patterns of tree distribution in terms of structure after these profound changes? It is important to characterize the communities in human dominated landscape in terms of its richness, diversity and assemblages for knowing the stability and viability of the system for long term existence (Anitha et al., 2009).

Though several studies have investigated vegetation structure in the rain forests of Togo (Adjossou, 2009; Akpagana, 1989) many years ago, there is a need to update the knowledge about the state and tree species composition of these forests in current time. Based on these facts, the composition and vegetation structure in the ecological zone IV was studied by collecting data to answer the second research questions: what is the species composition of the remaining tree community?

The disturbance from the surrounding population in the form of cutting and illicit felling, lopping and fuel wood collections, Non timber forest products (NTFP) collection, conversion of forest into coffee and cocoa farms, grazing etc. are a subject of concern in the long term existence of the forest area. In this context, it is important to answer the third research question: what are the disturbance factors in the study area?

Furthermore, the country has recently joined the international Reducing emissions from deforestation and forest degradation (REDD+) initiative with the ambition to create a new incentive system to protect and restore the degraded forests and ecosystems(MERF[1], 2013).The objectives of this study are: (i) to assess the spatial patterns of tree species; (ii) to study species diversity of tree communities; and (iii) to characterize the surrounding human activities and its impact on tree species in the study area. The present study is significant in generating useful baseline data in order to manage remaining forests in the region and to guide the policies in the strategic choices and implementations of REDD+ projects in order to conserve and manage the native tree species in this area.

MATERIALS AND METHODS

Description of the Study area

The ecological zone IV, which is the study area, is located in the southern part of Togo Mountain, south-west of Togo, on the border between Togo and Ghana. The ecological zone IV, occupies a territory, which extends between the latitudes 6° 15 and 8° 20 and the longitudes 0° 30 and 1°. It covers an area of about 65 000 ha (Figure 1).

The climate prevailing in this area is a Guinean mountain climate characterized by a long rainy season (March-October) interrupted by a slight decrease in August or September. The average annual temperatures vary between 21 to 25°C and the total annual rainfall varies between 1400 to 1700 mm. This zone contributes significantly to species richness in Togo (Adjossou, 2009). It is the current domain of semi-deciduous forests. The main species encountered are *Khaya grandifolia, Antiaris africana, Milicia excelsa, Terminalia superba, Parinari glabra, Erythrophleum suaveolens* (Adjossou, 2009; Akpagana, 1989).

The study area shows a strong topographic heterogeneity. The average altitude is 800 m, with peaks at Djogadjèto (972 m) and Liva (950 m). A network of complex secondary rivers covers the area with three catchment areas: the basin of the lake Volta in the west of the Mounts, basins of the Mono River and Zio River in the east of the mounts. The population distribution and land management varies across the area, with implications for changes in tree species composition, abundance, and diversity.

Data collection

Data were collected from 170 randomly selected plots over the
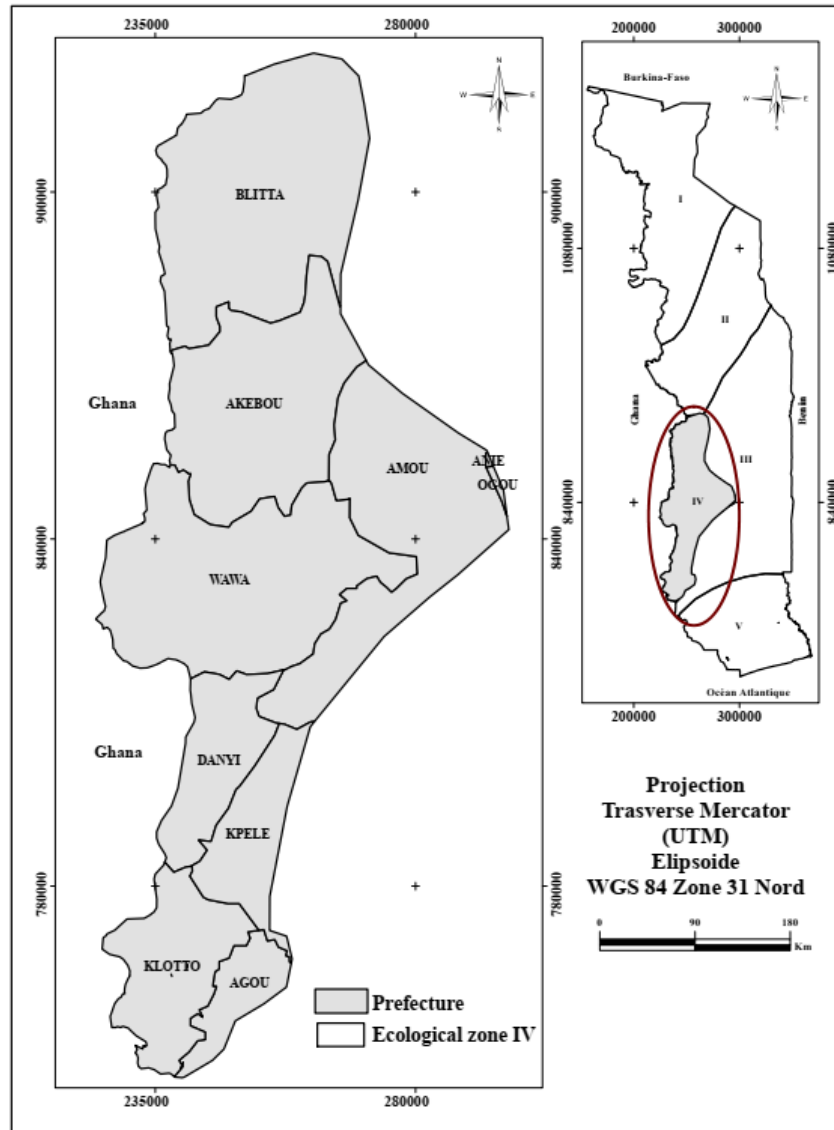
Figure 1. Study area.

entire study area. Circular plots were selected for dense forests, agroforests, plantations and woodland / wooded savannas and rectangular plots (Kokou 1998) for gallery forests. In the circular (20 m radius) and the rectangular plots (50m x 10m) all woody plants with Diameter at Breast Height (DBH) >10 cm were identified at species level, counted, and height was measured. Forest strata were defined using an available land-cover map of the area. In order to characterize the ecology of the species, topographic situation, vegetation type, stratum overlap and surrounding human activities were characterized in each of the 170 plots.

Data analysis

For the first objective, an ascending hierarchical classification (AHC) was performed, using Bray-Curtis dissimilarity metric, and Ward's minimum variance, which are clustering methods recommended for vegetation cluster analysis (Borcard et al., 2018). The AHC allows examining and validating the presence of ecologically meaningful clusters among our sampled plots designed for the study. First, the Bray–Curtis distance matrix was computed using the abundance data, with species in the columns and sites in ascending order of altitude in rows. Then, hierarchical Ward's minimum variance clustering on the Bray–Curtis distance matrix was performed. The Bray-Curtis index varies from 0 (same species composition and relative frequencies) to 1 (no shared species) for each pair of land cover type (Abotsi et al., 2020). Structural composition was analyzed by comparing the distribution of tree diameter classes. Based on the individuals recorded in the discrete plot samples, vegetation data were quantitatively analyzed for relative density, relative frequency, and relative dominance. The importance value index (IVI) of tree species was determined as:

IVI= Relative frequency + Relative density + Relative dominance   (1)

Based on the IVI values, species associations within these assemblages and characterized each community by these species

Table 1. Scoring of level of perturbation.

Classification	Description
1	Excellent, with few signs (<2%) of human disturbance through logging or farming or fire damage with a good canopy
2	Good, <10% disturbance. Logging damage restricted or light and well dispersed. Fire damage none or peripheral
3	Slightly perturbation. Obviously disturbed or degraded and usually patchy, but with good forest predominant; Maximum 25% with serious scars and poor regeneration. Maximum 50% slightly disturbed, with broken canopy
4	Obviously disturbed and patchy, but with bad tree predominant; 25-5% serious scars and poor or no forest regeneration; or almost all heavily burnt, about 75% degraded
5	Very poor, more than three quarters disturbed (forest with coherent Canopy >75% broken)
6	No forest left, deforested with plantation or farm. Less than 2% forest

associations were identified. Tree basal area (BA$_i$) was calculated using the following equations:

$$BA_i\ (m^2) = \frac{(DBH/100)^2}{4*\pi},$$

(2)

Where DBH is the diameter at breast height in centimeter. The total BA for each plot was obtained by adding all trees BA in the plot. Species accumulation curve for tree species was obtained by computing the cumulative number of species encountered with increase in the number of plots (or total area) sampled (Anitha et al., 2010). The species accumulation curve is the cumulative number of species recorded as a measure of sampling effort.

For the second objective, several measures were formulated for biological richness. The most common species diversity indices are Shannon index and Simpson's heterogeneity indices (Kouki,1994; Swindel et al.,1984). Shannon and Simpson's indices integrate both species number and the relative abundance of the different species, and their numerical value rises as the number of species increases and their occurrences even out. The Shannon and Simpson indices were calculated from the cover-abundance of species in each plot. The Shannon Index is defined as:

$$H' = -\sum_i^s pi \log_2 pi$$

(3)

Where s equals the number of species and pi is the proportion of the total number of trees belonging to species i.
The Simpson Index is defined as:

$$D = \sum pi^2$$

(4)

Where pi is the proportion of the total number of trees belonging to species i. As biodiversity increases, the Simpson Index decreases. Therefore, to get a clear picture of species, dominance (Do) I s defined as:

$D_0= 1-D$ (5)

The Pielou Index (E) is defined as:

$E = H'/\log s$ (6)

where, H'= Shannon index, S= number of species in the sample.
The Simpson Index(D) and the Pielou Index (E) are considered as a measure of species dominances and a measure for evenness of spread, respectively (Magurran, 1988). R studio version 3.4 a free software environment for statistical computing and graphics, was used for the estimation of species diversity (Gotelli and Colwell, 2011).

Statistical significant differences in tree density and diversity between trees communities analyzed using analysis of variance (ANOVA), and Kruskal–Wallis test when data could not meet the assumptions for parametric tests when transformed. The assumption of normality was assessed using the Shapiro–Wilk tests (Crawley, 2012). If they are normal, then an ANOVA for comparison among trees communities was used. If data are not normal, a non-parametric Kruskal Wallis test was used. Descriptive statistics (frequencies, and percentages) generated using Excel were also used to analyze the data.

In order to characterize the disturbance factors in the area, the surrounding human activities, in each of the 170 plots were noted in the field. This characterization is based on field observation. The six points score was used in describing level of perturbation (Table 1) (Appiah, 2013). The frequency of disturbance factor was assessed in the study.

RESULTS

Tree species distribution in Togo ecological zone IV

Tree species communities

The cluster analysis revealed that five forest communities could be formed based on the composition of tree species at different sites, although few plots deflected from its designated categories (Figure 2). The dendrogram obtained from the distance matrix of land cover types indicates that there are affinities between the flora within each group (Figure 2). Indeed, 5 floristic group are identified for species in ecological zone IV according to land cover types.

In Group 1: A total of trees (DBH>10cm) belonging to 110 species were recorded. Most dominant tree species represented in this group according to IVI value are *Lophira lanceola*ta (IVI =29.22), *Pterocarpus erinaceus* (IVI= 25.21), *Daniellia oliveri* (IVI= 23.70)*, Crossopteryx febrifuga* (IVI= 17.84) (Table 2). Based on IVI value, it can be concluded that the area is dominated by *Lophira lanceolata, –Pterocarpus erinaceus*, –*Daniellia oliveri, –Crossopteryx febrifuga association* (Table 2).The other major species in this group are *Ficussur, Margaritaria discoidea, Lanne abarteri, Lannea acida, Terminalia glaucescens, Burkea africana, Afzelia africana, Vitex*
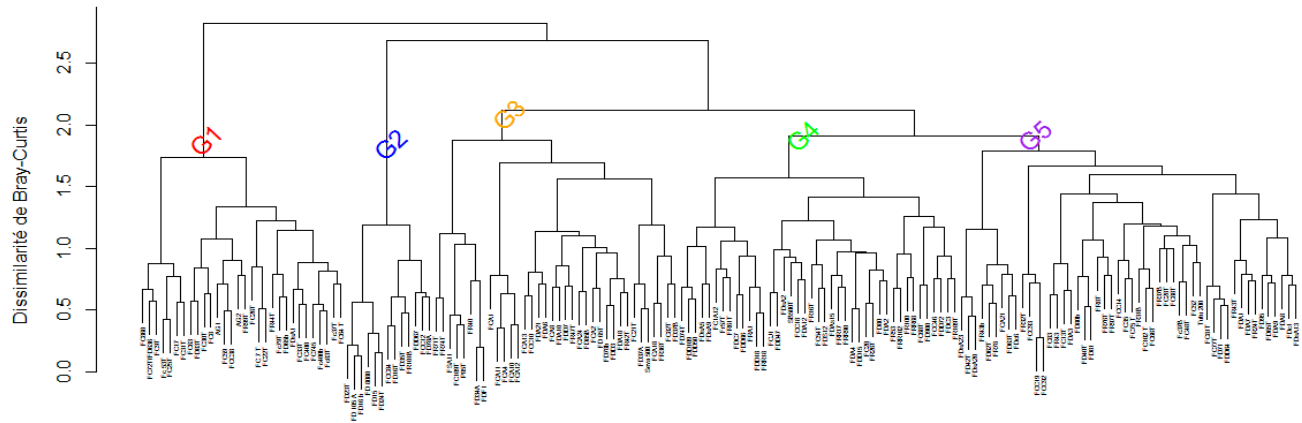
Figure 2. Hierarchically clustered dendrogram on the Bray–Curtis distance estimated using abundance data. Hierarchical clustering was done using Ward's algorithm, the y-axis represents the Bray–Curtis distance shared among each cluster.

doniana, Cussonia arborea, Syzygium guineense and *Albizia zygia.* This group is characterized by guinea savannah species.

In Group 2: A total of trees (DBH>10cm) belonging to 53 species were recorded in the group 2. The area is dominated by *Theobroma cacao* (IVI = 102.65), *Elaeis guineensis* (IVI = 13.74), *Morinda lucida* (IVI = 9.53*) and Pseudospondias microcarpa* (IVI = 9.03*)* association (Table 2). The group is also characterized by the presence of *Ceiba pentandra, Milicia excelsa, Ricinodendron heudelotii, Terminalia superba, Triplochiton scleroxylon, Sterculia tragacantha, Pycnanthus angolensis, Albizia adianthifolia, Albizia lebbeck, Spathodea campanulata, Discoglypremna caloneura.* The group 2 is characterized by cocoa plantation system species.

In Group 3: The area is characterized by *Elaeis guineensis- Persea americana-Albizia zygia- Alstonia boonei- Terminalia superba* (IVI-26.88, 25.32, 18.97, 12.96 and 12.83 respectively). This formation is also distinguished by species such as *Ceiba pentandra, Khaya grandifoliola, Theobroma cacao, Albizia adianthifolia, Cola gigantea, Cola nitida, Pseudospondias microcarpa, Mangifera indica, Erythrophleum suaveolens, Ficus mucuso.* This group is characterized by agroforestry system species.

In Group 4: This group is a dominant association of *Cola gigantea–Senna siamea–Erythrophleum suaveolens* species (IVI values of 16.00, 13.81 and 13.58 respectively). This group is characterized by the presence of species such as *Anogeissus leiocarpa, Holarrhena floribunda, Margaritaria discoidea, Manilkara obovata* and *Gmelina arborea.* This group is a characterized by secondary forest species.

In Group 5: This group is mainly a composition of species such as¨ *Pycnanthus angolensis, Ceiba pentandra, Pseudospondias microcarpa, Albizia adianthifolia, Aubrevillea kerstingii, Morinda lucida, Khaya grandifoliola* and *Ficus sur.* The major species association is *Sterculia tragacantha–Funtumia africana–Milicia excelsa* (IVI values of 12.95, 12.32 and 11.15 respectively). This group is characterized by dry deciduous species.

Tree communities growing dynamics

Stems were classified into various size classes and higher number of individuals was found in the lowest classes indicating a regenerating population. The size class distributions exhibited the roughly negative exponential or 'inverse J', curves typical of natural forests (Figure 3). The big trees >= 100 cm are scare in the area. As the diameter increased, there was a decrease in the number of stems. The lowest diameter class (10 - 20 cm) had the highest number of stems, species and family.

Species composition and richness

The species accumulation curve indicates that most species present in the study area were included in samples because the curves approach an asymptote (Figure 4).

In total, 5782 trees (DBH >10 cm) representing 243 species belonging to 44 families (170 genera). Out of these, 30 families comprising 86 genera, 110 species, and 1457 trees were recorded in group 1; 19 families representing 41 genera, 53 species, and 590 trees were recorded in group 2; 116 species belonging 89 genera, 30 families, and 1131 trees were recorded in Group 3 and 4 recorded 1441 trees belonging to 158 species among 124 genera and 37 families and Group 5 recorded

Table 2. Important value index (IVI) of 15 most important species > 10 cm in the different group.

S/N	Group 1		Group 2		Group 3		Group 4		Group 5	
	Species	IVI		IVI		IVI		IVI		IVI
1	Lophira lanceolata	29.22	Theobroma cacao	102.65	Elaeis guineensis	26.88	Cola gigantea	16	Sterculia tragacantha	12.95
2	Pterocarpus erinaceus	25.21	Elaeis guineensis	13.74	Persea americana	25.32	Senna siamea	13.81	Funtumia africana	12.32
3	Daniellia oliveri	23.7	Morinda lucida	9.53	Albizia zygia	18.97	Erythrophleum suaveolens	13.58	Milicia excelsa	11.15
4	Crossopteryx febrifuga	17.84	Pseudospondias microcarpa	9.03	Alstonia boonei	12.96	Anogeissus leiocarpa	12.05	Pycnanthus angolensis	10.62
5	Ficus sur	10.13	Ceiba pentandra	8.95	Terminalia superba	12.83	Holarrhena floribunda	10.04	Ceiba pentandra	10.39
6	Margaritaria discoidea	10.02	Milicia excelsa	8.14	Ceiba pentandra	12.56	Margaritaria discoidea	8.24	Pseudospondi asmicrocarpa	10.3
7	Lanne abarteri	9.99	Ricinodendron heudelotii	7.46	Khaya grandifoliola	10.76	Manilkara obovata	6.16	Albizia adianthifolia	8.93
8	Lannea acida	7.75	Terminalia superba	6.98	Theobroma cacao	10.36	Gmelina arborea	5.76	Aubreville akerstingii	8.83
9	Terminalia glaucescens	7.73	Triplochiton scleroxylon	6.8	Albizia adianthifolia	10.01	Terminalia glaucescens	5.66	Morinda lucida	8.3
10	Burkea africana	6.77	Sterculia tragacantha	6.77	Cola gigantea	8.72	Macaranga barteri	5.32	Cola gigantea	7.3
11	Afzelia africana	6	Pycnanthus angolensis	6.55	Cola nitida	7.52	Pseudospondias microcarpa	5.2	Trilepisium madagascariense	6.85
12	Vitex doniana	5.89	Albizia adianthifolia	6.38	Pseudospondias microcarpa	5.69	Terminalia macroptera	4.92	Ficus sur	5.93
13	Cussonia arborea	5.37	Albizia lebbeck	6.26	Mangifera indica	5.51	Mangifera indica	4.61	Trichilia prieuriana	5.66
14	Syzygium guineense	5.32	Spathodea campanulata	5.92	Erythrophleum suaveolens	4.79	Ficus sur	4.58	Cleistopholis patens	5.49
15	Albizia zygia	5.09	Discoglypremna caloneura	5.59	Ficus mucuso	4.56	Albizia adianthifolia	4.53	Khaya grandifoliola	5.33

1163 trees belonging to 140 species among 107 genera and 36 families.

The most abundant species at the scale of the study area included species with high economic values belonging to the categories of timber species (Khaya grandifoliola, Milicia excelsa, Terminalia superba etc.), medicinal species (Alstonia boonei) and spice species (Monodora myristica and Xylopia aethiopica). In addition to multipurpose species (fertilization, soil restoration, shading, firewood, fruits etc.) and pioneer species like Albizia adianthifolia, Funtumia Africana, Ficus mucuso, Ficus sur, Holarrhena floribunda, Margaritaria discoidea, Morinda lucida, etc. The presence of pioneer species proves that the habitat had undergone serious anthropogenic disturbance event (logging, clearing, vegetation fires).

Figure 5 indicates families with at least 3% composition in the tree community. The Fabaceae families collectively comprised more than 20% of the entire trees sampled. Other families substantially represented in the vegetation are the Malvaceae, Moraceae and the Combretaceae. Collectively, they comprised 43.55% of ecotone trees. The studied forests communities showed differences in terms of density, diversity, and species richness. The various ecological parameters such as density, species richness, and different diversity indices have been measured/calculated for species > 10 cm (Table 3). Mean tree density varied spatially across different groups, ranging from 408.96±202.17 (Group 1) to 273.90± 193.19 (Group 4) (Table 3). The higher basal area of trees (27.99 ± 25.58 m^2/ha) is in Group 3 (agroforestry system species)

and the lower basal area (15.84 ± 13.44 m^2/ha) is in Group 4 (secondary forest).

Diversity of tree species in the study plots calculated using the Shannon Weiner index (H') showed that the highest diversity was in Group 5 (2.05 ± 0.61) and the lowest diversity was in group 2 (1.19 ± 0.64). The Pielou index was the highest (0.87 ± 0.11) in Group 5 (dry deciduous forest). This result showed that the group 5 is facing few disturbances and the vegetation is the most closed to natural vegetation.

The One-Way ANOVA was carried out for the species richness (F $_{(1, 168)}$= 0.246, p (0.621) >0.005), the Shannon index (F $_{(1, 168)}$= 0.547, p (0.46) >0.005) and the tree density (F $_{(1, 168)}$ = 6.842, p (0.00972) >0.005) in the five groups. The result revealed that the means are not significantly different at 95% confidence limits for species
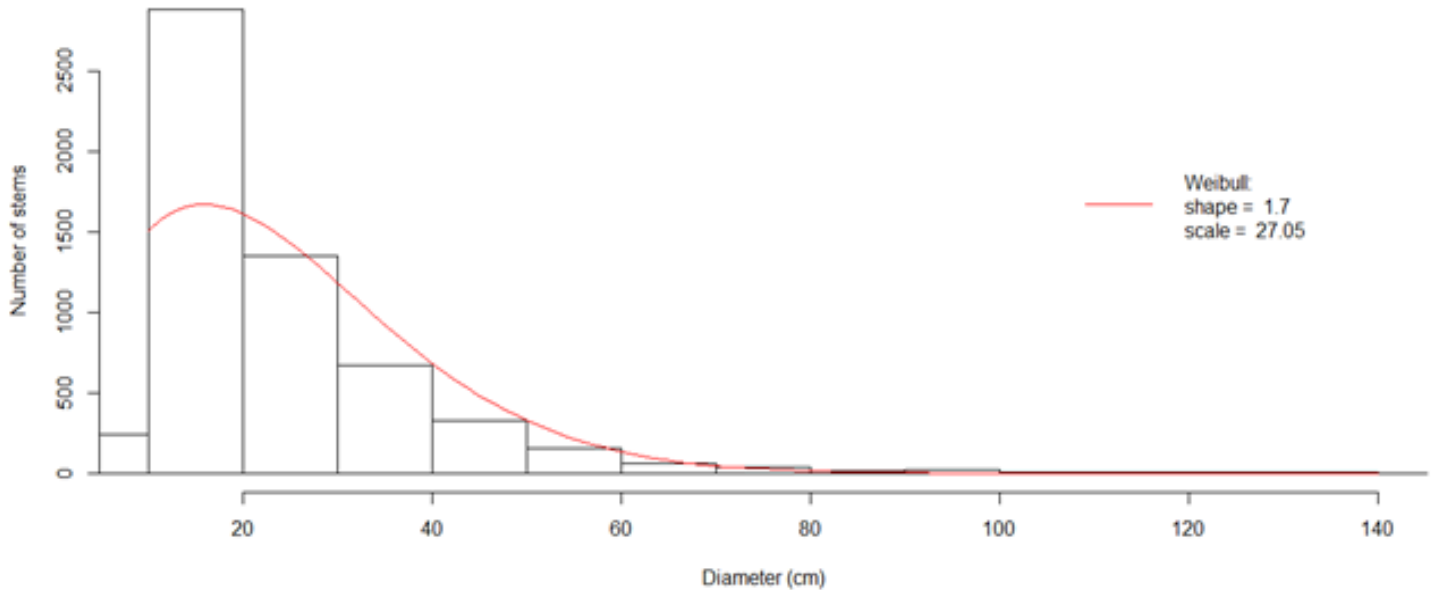
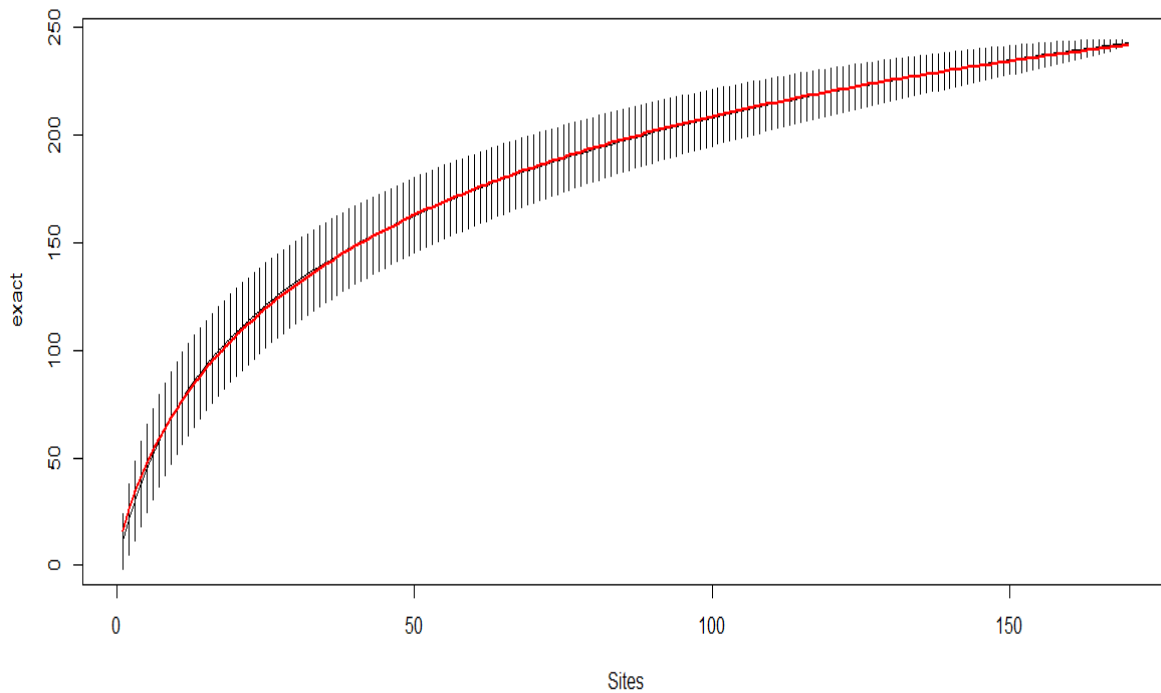**Figure 3.** Class distribution of tress with DBH>10 cm recorded in the study.

Figure 4. Species accumulation curve for tree species at study sites as a function of sampling effort.

richness, Shannon index and tree density.

Disturbance factors in the study area

Based on field observations in the study area,

disturbance factors were identified in the study area. The analysis of the disturbances factors showed that more than 50% of the plots in the study area are threatened by agriculture, 23% by logging and 13% by wildfire. Only 4% of the plots are undisturbed (Figure 6).

Others disturbances factors like grazing, cutting and
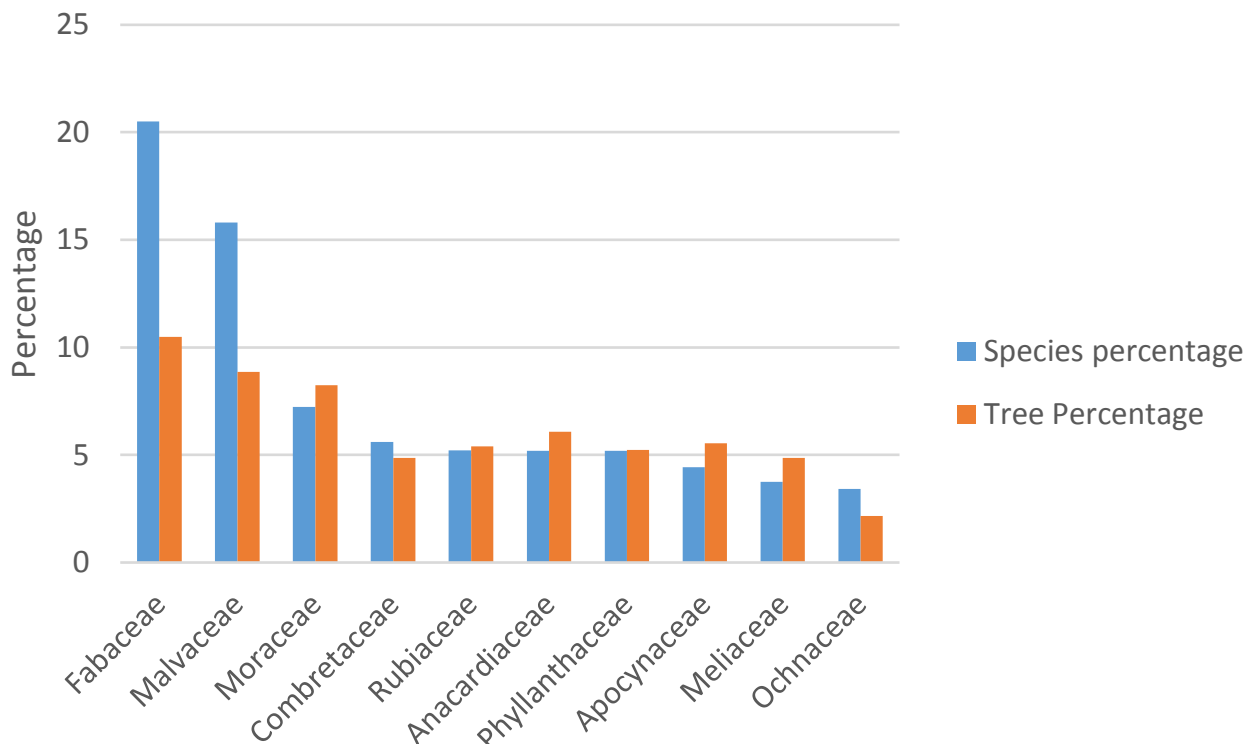
Figure 5. Families with at least 3% in tree population.

Table 3. Basal area, diversity and Pielou equitability index.

Group	Number of plot	Basal area	Density (tree/ha)	Shannon index	Pielou equitability index
1	30	16.59 ± 10.64	408.96± 202.17	2.00 ± 0.71	0.82 ± 0.10
2	13	21.28 ± 14.89	402.84± 239.41	1.19 ± 0.64	0.56 ± 0.23
3	36	27.99 ± 25.58	313.90 ± 215.53	1.92 ± 0.58	0.83 ± 0.12
4	50	15.84 ± 13.44	273.90± 193.19	1.74 ± 0.68	0.80 ± 0.20
5	41	27.77 ± 21.16	310.91± 205.79	2.05 ± 0.61	0.87 ± 0.11

illicit felling (Photos 1 and 2), fuel wood collections and NTFP collection were noted in the study area. Grazing from cattle, goat and sheep is also source of disturbance in the area. The area is also surrounded by the conversions of secondary forest and fallow areas to agroforestry and monoculture plantations.

DISCUSSION

Compared to Adjossou (2009) and Akpagana (1989) researches, diversity index recorded in this study is very low. Two possible explanations to these marked differences were identified. First, the methodology used in this study is different from the one used in Adjossou (2009). In this study, all species with DBH > 10 cm when the previous studies recorded all species found in the area were recorded. Secondly, low diversity indices in

this study compared to previous studies in the same area is probably due to species loss. Extinction of species in the study area has already been reported by Adjossou (2009). Several studies (Hoffmeister et al., 2005) has also shown extinction of species in very fragmented habitats.

The presence of many pioneer species or secondary species in the study areas proves that the habitat had undergone serious anthropogenic disturbance events, which can contribute to species loss in the area. When the anthropogenic disturbance is more intense than the natural disturbance regime, the forest shows a lager seed bank mostly composed of pioneer species or secondary species (Eilu and Obua, 2005). Further research is needed to update the complete floristic list of forest zone in Togo according to the methodology used by Adjossou (2009) and Akpagana (1989). Different categories of threats to species loss were examined and described in
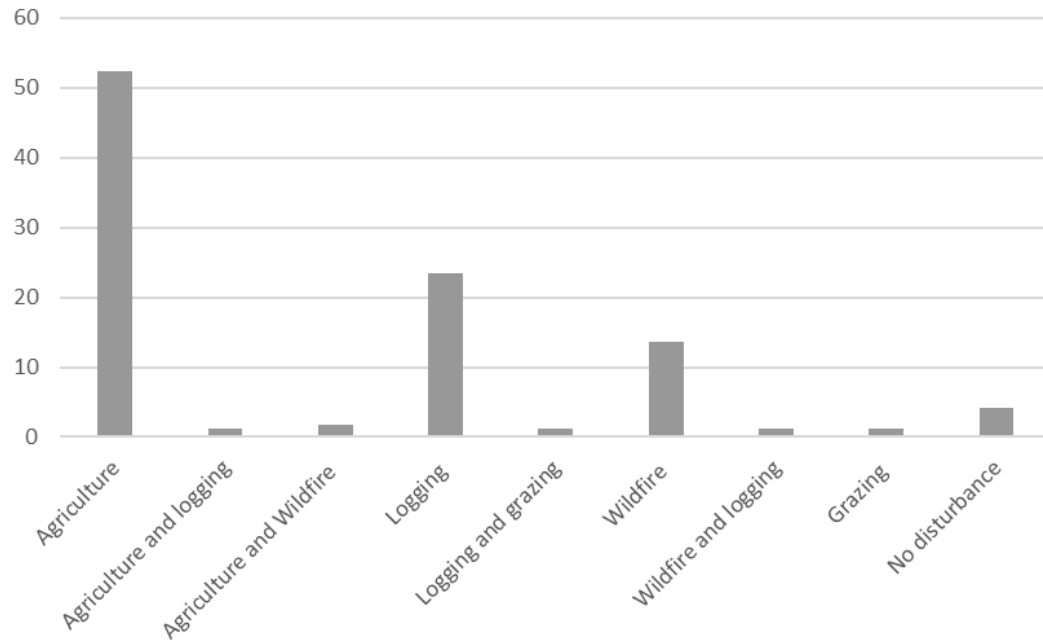
Figure 6. Type of disturbance identified in the study area.

Photo 1. Tree felling and burning.

the study area: increasing anthropogenic pressure, such as grazing, tree felling and clearing for forest for

agriculture, wildfires and logging practice, as well as climate change effects. These threats have been also

Photo 2. Tree felling for agriculture.

observed by Adjossou (2009) study in that area. Under intense wildfires, and extensive extraction of timber and wood products or other disruptive land uses, forests are sometimes left fragmented leading to the extinction of certain seed-dispersing animals, and severely limiting regeneration of rare plant species (Appiah, 2013).

Grazing was another major source of disturbance. The area is also surrounded by the conversions of secondary forest and fallow areas to agroforestry and monoculture plantations. Until 1989, most forest in the study area were converted into high-yielding coffee and cocoa fields. Conversion was possible thanks to the introduction and use of chainsaws.

Globally, many factors have been attributed to forest loss in the tropical forest; it is believed to be generally driven by a complex interplay of various forces. These range from demographic changes, poverty, policy responses of countries to fires, and anthropogenic disturbances (such as logging, agricultural expansion) and climate change (Novick et al., 2003). Several forest areas fragmentation, as well as repeated forest destruction, has resulted in the elimination of indigenous species and the development of degraded landscapes dominated by invasive species (Powell et al., 2011).

Spatial variations in plant density and diversity occur from complex interactions based on local ecological conditions, among other factors. In this study, mean tree density varied spatially across different formation, ranging from 408.96± 202.17 (Group 1) to 273.90± 193.19 (Group 4). The stand density in Group 1 (guinea savannah species) is comparable to the one reported by Adjossou (2009) (507 ind/ha) in the same area. The density rate is also comparable to mean tree density per hectare(for trees with DGB>10 cm) reported from Asase and Tetteh (2010) (of 470 in a natural forest). However, the tree density is also comparable to other tropical forests of Ghana (231.81 tree/ha; Attua (2003)), tropical forest in India (556 mean stand density trees/ha) (Naidu and Kumar, 2016).

The diameter distribution of trees has been often used to represent the population structure of forests. The present assessment presented a reverse J-shaped distribution, suggesting uneven-aged forests for sustainable reproduction and regeneration (Vetaas, 2000), with a sufficient number of young individuals with intermediate DBH between [10, 30] cm to replace the old mature stand. Tree distribution across different diameter classes revealed larger trees species with DBH > 80 cm are few in the area. The finding could be associated with forest degradation and deforestation reported by earlier

studies (Adjossou, 2009).

This study identified the Fabaceae, Malvaceae and Moraceae as the most represented families in the tree vegetation of the study area. Other also substantially represented families were the Meliaceae, Rubiaceae, Euphorbiaceae, and the Combretaceae. This observation is in close agreement with the findings of Adjossou (2009) that the most represented families in the forest zone in Togo in term of number of species are Rubiaceae, Euphorbiaceae, Fabaceae, Moraceae and Apocynaceae. Another study of Asase and Oteng-Yeboah (2007) and Asase et al. (2009) found that the Fabaceae and Combretaceae were dominant tree families in Guinean savanna vegetation. Elsewhere, Felker (1981) had attributed the abundance of Fabaceae trees to their role in maintaining nitrogen balance of agro-ecosystems for which reason they are protected and managed on farms. The study also found that *Theobroma cacao*, *Pterocarpus erinaceus*, *Persea Americana* and *Cola gigantea* were abundant. Most of these trees are of nutritional and economic significance in the study area. The abundance of economic trees in the study area is mainly due to the forestland use in the area. Most of the forestland is converted to agriculture land by agroforestry system. The results are also in line with those obtained by Adjossou et al. (2019) who studied the Forest land use and native trees diversity conservation in Togolese mega hotspot, Upper Guinean in West Africa. The Shannon index (H') values for tree species reported from this study ranged from 2.05 ± 0.61 (Group 5) to 1.19 ± 0.64 (Group 2). The type of forest for these two groups can explain the different Shannon index in the two groups. The Group 5 (dry deciduous forest) is more diverse than Group 2 (cocoa plantation). This observation also revealed that Group 5 is a forest with low disturbance from human activities compared to Group 2. The results are comparable to those reported by Uniyal et al. (2010; 0.70-3.08) from other different tropical forests.

In this study, mean basal area (m^2/ha) which varies from 15.84 ± 13.44 (Group 4) to 27.99 ± 25.58 (Group 3). These values are lower than those reported by Adjossou (2009; 50-113 m^2/ha) in the same area and may be explain by the reduction of species in the area since 2009. The differences in the basal area of tree layers among the study plots may be due to differences in altitude, species composition, age of trees, and extent of disturbances and successional strategies of the stands (Naidu and Kumar, 2016).

Conclusion

Tree species density, distribution, and population structure analyzed in this study should be useful to effective management of tree diversity in sub humid mountains ecosystems in south-west of Togo. Documenting the patterns of tree diversity and their distribution provides a good database, useful for management measures in these forests. The preservation of these ecosystems is crucial not only for conservation of their rich biodiversity, but also for meeting the basic needs of the local population. Therefore, this paper calls for an urgent conservation plan to conserve biological diversity.

The localized processes or disturbances such as wildfires, shifting cultivation, and logging appear to have had a significant impact on the community composition and species distribution pattern at the study area. The study area is poor in richness and diversity compared to previous studies in the area. Many tree species usually found in sub humid mountains ecosystems in south-west Togo that have economic significance are in very low numbers, especially in the adult populations. The impact of human activities is significant on the plant resources by reducing the population of larger plants.

Quantitative analysis of tree species diversity recorded in this study may provide baseline information for formulating conservation and management strategies for these forest zones.

Several measures must be taken to support recovery of the trees species and ecosystem in the study area: (i) develop reforestation based on assisted natural regeneration, which encourages the promotion of fast growing indigenous species; (ii) establish plantations in severely degraded areas of the site ;(ii) limit dependence of the population on wood energy; and (iii) raise farmers' awareness of biodiversity, its importance and the need to preserve it through sustainable management.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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