Floristic Composition and Structure in Relation to Elevation in the Togo Plateau Forest Reserve in Ghana

Gilchrist K. Faith Dogor, Emmanuel Acquah, and Alexander K. Anning

ABSTRACT

Plateau ecosystems are of special scientific and conservation interests as they harbour rich plant diversity and exhibit considerable spatial variability along elevation gradients. In this study, variations in floristic composition and structure in relation to elevation were studied in six-fringed communities Hohoe (HH), Alavanyo (AL), Santrokofi (SA), Akpafu (AK), Bowuri (BO), and Nkonya (NK) of the Togo Plateau Forest Reserve in Ghana to help provide explicit and effective management of this ecological hotspot. A total of 180 plots (each measuring 25m × 25m) were demarcated across the six communities for sampling of trees (DBH measured at 1.3 m above ground ≥ 10 cm). Smaller nested plots, measuring 5m × 5m and 1m × 1m, were used for sampling saplings (DBH < 10 cm, height > 1.5 m) and seedlings (DBH < 3 cm, height < 1.5 m), respectively. Species identity and abundance and elevation were recorded for each plot. Relationships of elevation gradient with vegetation attributes were analysed using simple linear regression. A total of 281 plant species (164 trees, 60 saplings and 57 seedlings) belonging to 66 families were recorded in the study. Leguminosae, Apocynaceae and Euphorbiaceae were the most dominant families across and along the elevation gradient. Average basal area of trees across the six communities was 44.72 m²/ha (ranged from 57.10 m²/ha at BO to 33.10 m²/ha at AL) whereas the Shannon-Weiner Index (H') averaged 3.99 (ranged from 4.14 m²/ha at BO to 3.89 m²/ha at AL) and evenness index averaged 0.96 (ranged from 1.00 at BO to 0.92 at AL). The saplings and seedlings showed a similar pattern of composition and structure as the trees. The geographical locations of the study communities, which somehow correspond with different elevations of the plateau (i.e., BO, NK occur in lower elevations, SA, AL in mid elevations and HH, AL in higher elevations), was observed to have marginally influenced the composition and structure of the vegetation on the landscape. The most important trees listed in the study were *Ceiba pentandra*, *Albizia zygia*, and *Terminalia superba*. The saplings were *Acacia cameronensis*, *Microdesmis puberula* and *Cnestis ferruginea*. The seedlings were *Chromolaena odorata*, *Palisota hirsuta* and *Costus afer*. The most important tree species listed were distributed along a broad range of elevations. These results generally demonstrate the high floristic diversity of the Togo Plateau and the influence of elevation gradient on this, which should help in understanding of the composition and structure of several plateau ecosystems in Ghana and elsewhere.

Keywords: Togo Plateau Forest Reserve, Plateau ecosystem, Elevation gradient, Plant diversity.

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I. INTRODUCTION

Plateau forests are one of the most ecologically complex and biologically rich ecosystems in the world [1]-[5]. These ecosystems provide a series of elevation gradients that drive the patterns of species composition and structure [6]-[8]. Plateaus are known to play a vital role in supporting life of communities fringing it, in particular, and the planet as a whole [6], [9], [10]. They provide many ecosystem services which can be grouped as supporting services (soil formation, nutrient cycling), provisioning services (food, wood, water), regulation services (water regulation, climate regulation, land degradation) and cultural services (recreational,

consciousness, religion) [9]-[11].

Despite their importance, available data suggest a steady decline in biodiversity from these unique ecological units [9], [10], leading to calls for their conservation [4], [6], [12]. Ecologists have also predicted a 0.2% loss of plateau ecosystems each year, particularly in Africa, Amazonia, and parts of South-East Asia, should the current rate of degradation continue [10], [12]. Further, the existing gaps in knowledge concerning the composition and structure of plateau ecosystems [14], [13], make it difficult to comprehend their function, conservation, and transformations, particularly with elevation and climate [12], [13]. Understanding the composition and structure of these

ecosystems and their drivers as well as managing them sustainably require more floristic surveys at a variety of scales [10], [12]. Several factors drive vegetation composition and structure of plateau ecosystems, of which elevation is one of the most well documented [10], [12]. Elevation plays an important role in controlling the ecological and physiological adaptations of various growth forms of plants [7], [14]. These are often accomplished through its regulatory role in the spatial and temporal distribution of climatic factors such as solar radiation, soil formation processes, precipitation, temperature, resource availability, soil organic matter and carbon storage [12], [15]. As a consequence, species diversity has been observed to increase with altitude until mid-elevations and then decrease in tropical forests [6], [16].

The Togo Plateau Forest Reserve is considered a rich biodiversity hotspot, having diverse species of flora and fauna. The plateau covers a total forest area of 14,763 hectares and stretches from Volta Region to Oti Region in Ghana. The reserve is characterized by horizontal layers of sedimentary rocks, a wide range of elevation, hundreds of escarpment and rocky mountain provinces. Its high topographic complexity has created different life zones that support different vegetation communities. The plateau, therefore, provides a good ecosystem for evaluating the relationship between species composition and structure and elevation [3], [7], but to the best of our knowledge, no scientific quantitative studies have been documented for this ecosystem. Consequently, its ecological needs and major threats are poorly understood, and the conservation requirements of this area are not appreciated [3], [7]. This dearth of scientific information presents a major limitation for effective management and conservation of the reserve.

This study investigates the floristic composition and structure of the Togo Plateau Forest Reserve in Ghana in relation to elevation. Generally, the study is expected to help elucidate the current state of the vegetation and provide the critical baseline floristic information for effective conservation planning and management of this plateau ecosystem. The study addresses two key questions: a) what is the floristic composition and structure of the Togo Plateau Forest Reserve? and b) how do the composition and structure of the plateau ecosystem change along the elevational gradient across the different fringed-communities? Elevation was expected to drive the patterns in species composition and structure in the communities around the TPFR in Ghana.

II. MATERIALS AND METHODS

A. Description of the Study Area

The Togo Plateau Forest Reserve (longitude 0°15'E and 0°45'E and latitude 6°45'N and 7°15'N) is surrounded by several communities. These communities include Hohoe and Alavanyo in the Hohoe municipality of the Volta Region, as well as Santrokofi and Akpafu in the Jasikan District and Bowuri and Nkonya in the Biakoye District in the Oti Region, all in the Republic of Ghana (Fig. 1). The geographical locations of the study communities to the plateau somehow correspond with different elevations (i.e., BO, NK occur in lower elevations, AK, SA in mid elevation and HH, AL in

higher elevations). The reserve, which covers an area of 14.76 hectares, was established by the British Colonial Administration in 1929 and gazetted in 1931 as a national reserve. The reserve lies in the wet semi-equatorial climatic zone and receives an average annual rainfall of between 1016 and 1210 mm. The dry season lasts 4-5 months and occurs between November and April. Temperatures are high throughout the year and range from 26 °C to 32 °C [29].

Fig. 1. The Togo Plateau Forest Reserve in the Volta and Oti Regions of Ghana showing the locations of the study communities.

B. Floristic Assessment

Six Communities (Hohoe, Alavanyo, Santrokofi, Akpafu, Bowuri and Nkonya) fringing the Togo Plateau Forest Reserve in Ghana, were selected for the study. Thirty plots (each of dimension 25 m × 25 m) were demarcated in each of the six communities (n=180) for sampling of trees. Plots were laid out perpendicular to the slope contours of the plateau (Fig. 1). In each plot, all trees (i.e., diameter at breast height, DBH, measured at 1.3 m above ground ≥ 10 cm) were identified and their DBH determined using a diameter tape. Plot elevations were recorded for all plots using the Global Positioning System (GPS, Garmin GPS-62). Smaller nested plots, measuring 5m × 5m and 1m × 1m were used to sample saplings (DBH < 10 cm, height > 1.5 m) and seedlings (DBH < 3 cm, height < 1.5 m), respectively. Plant identification was done with the help of a plant taxonomist and a local specialist, and the names were verified from the online resource, The Plant List (2013). Sampling was done between September 2017 and June 2018.

C. Data Analyses

Vegetation attributes such as frequency, density, basal area (BA), relative frequency, relative density, relative dominance, and importance value index (IVI) [21] were calculated for each species. The Shannon-Wiener index (H') [3] and evenness index [7] were also calculated. The relationship between elevation and vegetation attributes (species richness, Shannon diversity, and total basal area) were evaluated using the simple linear regression analysis. The non-metric multidimensional scaling (NMDS) ordination technique was used to explore and visualize the ecological distances among these communities based on species occurrences (i.e., presence or absence). The NMDS analysis was implemented using the “metaMDS” function in the R-package “vegan” [28]. The “stressplot” was used to

check the degree of fit between the ordination distance and the observed dissimilarity. The function “adonis” was used to test the group mean differences based on dissimilarities, and the “permutest” was used to evaluate the homogeneity of dispersions among the groups. All analyses were done using the R software package (version 4.0.3) [30].

III. RESULTS

A. Plant Species Composition in the Togo Plateau Forest Reserve in Ghana

A total of 281 plant species (164 trees, 60 saplings and 57 seedlings) belonging to 66 families were recorded from the study area (Table 1). These species included 4408 individuals

from Bowuri (BO), 4066 Nkonya (NK), 3904 in Akpafu (AK), 3729 in Santrokofi (SA), 3605 in Hohoe (HH) and 3261 in Alavanyo (AL) portions of the Togo Plateau Forest Reserve. The trees stand per plot ranged from 20 to 69, whereas saplings and seedlings numbered 11 to 38 and 8 to 30, respectively, per plot.

Among the families recorded in the study, Leguminosae topped the list with IVI of 9.81% and 4100 individuals. This is followed by Apocynaceae, Euphorbiaceae and Malvaceae each of which recorded IVI of 4.00%. Also, Rubiaceae and Sapindaceae recorded IVI of 3.38% each (Fig. 2). Family dominance showed a high degree of similarity among the study communities. This is evidenced from the dominance of the communities by the same set of families with Leguminosae being the most dominant in all cases (Fig. 2).

TABLE 1: GENERAL CHARACTERISTICS OF THE VEGETATION IN RELATION TO ELEVATION IN THE TOGO PLATEAU FOREST RESERVE IN GHANA

Attribute	BO	NK	AK	SA	HH	AL
Elevation (m a.s.l)	200.18-631.59	205.97-632.83	241.52-669.75	257.56-679.97	262.52-694.35	262.83-697.75
Richness	197	189	189	187	164	159
Number of individuals	4408	4066	3904	3729	3605	3261
Number of families	50	43	42	43	46	47
Trees						
Richness	114	107	107	106	85	83
Number of individuals	1635	1551	1501	1453	1387	1318
Mean Shannon diversity index	4.14	4.08	4.01	3.94	3.91	3.89
Mean Shannon evenness index	1.00	0.95	0.94	0.93	0.93	0.92
Basal area (m ² /ha)	57.10	55.92	44.58	38.53	38.10	33.10
Saplings						
Richness	60	59	58	56	53	52
Number of individuals	1496	1350	1300	1221	1193	1001
Mean Shannon diversity index	2.74	2.74	2.71	2.60	2.60	2.56
Mean Shannon evenness index	0.98	0.97	0.97	0.96	0.95	0.93
Seedlings						
Richness	41	41	38	38	37	25
Number of individuals	1277	1165	1103	1055	1025	942
Mean Shannon diversity index	1.74	1.69	1.67	1.64	1.62	1.59
Mean Shannon evenness index	0.93	0.93	0.93	0.92	0.91	0.85

Note: BO is Bowuri, NK is Nkonya, AK is Akpafu, SA is Sankofa, AL is Alavanyo, HH is Hohoe.

Fig. 2 Family dominance based on the relative importance value index (IVI, %) compared for each of the studied communities and the whole of the landscape.

B. Species Richness in the Togo Plateau Forest Reserve

The species richness values recorded in the plateau ranged from 83-114 for trees, 52-60 for saplings and 25-41 for seedlings. BO recorded the greatest number of species of 197 (114 trees, 60 saplings and 41 seedlings) while AL had the least value of 159 (83 trees, 52 saplings and 25 seedlings) (Table 1). Among the trees, an overall average Shannon-

Weiner Index (H') of 3.99 was recorded, but values varied across the six communities (ranged from 4.14 m²/ha at BO to 3.89 m²/ha at AL). Evenness index across the communities, on the other hand, ranged from 1.00 m²/ha at BO to 0.92 m²/ha at AL) with an average of 0.94 (Table 1).

Among the saplings, the average Shannon-Weiner Index (H') was calculated as 2.65 and varied across the six communities (ranged from 2.74 m²/ha at BO to 2.52 m²/ha at AL). Whereas the calculated values of evenness index varied across the six communities (ranged from 0.98 m²/ha at BO to 0.93 m²/ha at AL) with an average of 0.96 (Table 1).

In the seedling category, the average Shannon-Weiner Index (H') was calculated as 1.66 and varied across the six communities (ranged from 1.74 m²/ha at BO to 1.59 m²/ha at AL). Whereas BO, NK and AK had the highest calculated values of evenness index as 0.98, AL recorded the lowest value of 0.93 (Table 1).

The average basal area of trees was calculated as 44.72 m²/ha and varied across the six communities (ranged from 57.10 m²/ha at BO to 33.10 m²/ha at AL) (Table 1).

C. Analysis of the Vegetation Structure of the TPFR

1. Diameter distribution of trees, saplings, and seedlings in the TPFR

The trees, saplings and seedlings were grouped into six size-class distribution. The results showed that a greater

number of individuals are in the lower diameter classes (DBH 10-100 cm) in the TPFR with 3499 individual's ha⁻¹ (Fig. 3). About 220 individual's ha⁻¹ are however, found in the upper diameter classes (DBH>100) (Fig. 3).

Notably, the distribution of individuals among the six communities studied was generally similar across the diameter classes (Fig. 3). Across nearly all diameter classes, BO recorded the greatest number of individual trees whilst HH had the least.

2. The most important species in the TPFR

The most important trees in the TPFR were *C. pentandra* (IVI = 6.21%), *A. zygia* (6.04%), *T. superba* (4.89%), *A. toxicaria* (4.37%) and *C. gigantea* (4.2%; Table 2). These, species combined, accounted for 25.71% of the total IVI of all species in the study area. Eight other species recorded individual IVI values between 2.13% and 4.05%, whereas the remaining species recorded less than 2% IVI on the landscape. The importance of the tree species varied

somewhat across the communities, evidenced by different species dominating them. Although the six communities shared the 20 most abundant tree species on the landscape, *C. pentandra* was the most dominant in AK (IVI = 7.91%) and NK (7.06%), whereas *A. zygia* was the most important species in BO (8.34%), HH (7.29%) and AL (6.49%) respectively. The SA side of the reserve was, however, dominated by *A. toxicaria* with an IVI value of 6.90%. (Table 2).

Among the saplings, *A. camerunensis*, *M. puberula*, *C. ferruginea* and *E. calophylloides* emerged the dominant species across the landscape, with respective IVI values of 8.91%, 3.18 %, 3.13% and 3.09 % (Table 3). It is noteworthy that these species were also the most important in each of the six communities studied.

In the seedling's category, *C. odorata* (IVI = 29.55), *P. hirsuta* (IVI = 7.46), *C. affer* (IVI= 6.04) and *H. violacea* (IVI = 5.83) were the most dominant on the landscape (Table 4).

Fig. 3. Number of individuals recorded as a function of DBH Class attained in the TPFR in Ghana.

TABLE 2: RELATIVE IMPORTANCE VALUE INDICES (IVI, %) OF THE 20 MOST IMPORTANT TREE SPECIES IN THE TPFR IN GHANA

Trees	Combined	BO	NK	AK	SA	AL	HH
<i>Ceiba pentandra</i> (L.) Gaertn.	6.21	7	7.06	7.91	6.6	3.9	5.35
<i>Albizia zygia</i> (DC.) J.F. Macbr.	6.04	8.34	4.67	3.74	5.3	6.49	7.29
<i>Terminalia superba</i> Engl. & Diels	4.89	1.61	7	6.38	4.56	5.45	4.6
<i>Antiaris toxicaria</i> Lesch.	4.37	2.21	3.38	6.34	6.9	3.9	3.76
<i>Cola gigantea</i> A.Chev.	4.2	5.52	3.88	7.55	2.92	1.36	4.79
<i>Triplochiton scleroxylon</i> K. Schum.	4.05	5.14	5.17	4.94	3.29	2.8	3.32
<i>Ficus capensis</i> Thunb.	3.87	2.26	3.78	2.64	3.34	6.02	4.79
<i>Alstonia boonei</i> De Wild.	3.43	4.56	3.13	3.14	4.7	2.03	3.19
<i>Sterculia tragacantha</i> Lindl.	3.34	3.46	3.61	4.44	1.81	3.54	3.29
<i>Monodora myristica</i> (Gaertn.) Dunal	2.96	3.92	2.18	4.14	4.24	1.57	2.01
<i>Funtumia elastica</i> (Preuss) Stapf	2.82	2.21	2.53	0.47	4.04	4.51	2.63
<i>Bombax buonopozense</i> P. Beauv.	2.2	2.22	1.83	3.94	1.08	1.51	2.91
<i>Distemonanthus benthamianus</i> Baill.	2.13	1.99	1.47	0.9	2.14	4.13	1.66
<i>Canarium schweinfurthii</i> Engl.	1.99	1.46	2.76	1.27	1.6	3.36	1.22
<i>Petersianthus macrocarpus</i> (P. Beauv.) Liben	1.62	3.2	3.8	-	0.27	1.03	1.44
<i>Albizia ferruginea</i> (Guill. & Perr.) Benth.	1.4	1.89	0.64	0.97	2.29	0.85	1.78
<i>Dialium guineense</i> Willd.	1.4	1.88	0.23	1.84	1.41	0.51	2.69
<i>Azelia africana</i> Sm. ex Pers.	1.26	1.57	1.89	2.24	0.81	0.33	0.97
<i>Irvingia gabonensis</i> (Mildbr.) Okafor	1.23	4.63	1.12	-	0.21	0.18	1.16
<i>Nesogordonia papaverifera</i> (A. Chev.) Capuron ex N. Hallé.	1.21	1.56	0.71	1	2.16	1.41	0.28

TABLE 3: RELATIVE IMPORTANCE VALUE INDICES (IVI, %) OF 20 MOST IMPORTANT SAPLINGS IN THE TPFR IN GHANA

Saplings	Combined	BO	NK	AK	SA	AL	HH
	IVI	IVI	IVI	IVI	IVI	IVI	IVI
<i>Acacia camerunensis</i> Gand.	8.91	7.9	9.16	12.92	9.43	6.31	7.88
<i>Microdesmis puberula</i> Hook.f. ex Planch.	3.18	3.46	3.81	3.04	3.26	2.37	3.34
<i>Cnestis ferruginea</i> Vahl ex DC.	3.13	4.81	3.11	3.52	1.66	2.26	3.49
<i>Eugenia calophylloides</i> DC.	3.09	4.75	5.82	1.00	1.42	3.23	3.11
<i>Hoslundia opposita</i> Vahl	3.06	3.46	2.30	2.54	4.67	1.94	3.18
<i>Pachystela brevipes</i> (Baker) Baill.	2.86	1.30	4.71	3.60	3.56	2.70	1.67
<i>Leucaena glaca</i> (L.) Benth.	2.79	1.73	2.50	1.72	3.12	3.45	4.40
<i>Bauhinia rufescens</i> Lam.	2.77	3.88	2.50	3.24	1.90	2.16	2.88
<i>Holarrhena floribunda</i> (G. Don) T. Durand & Schinz	2.67	1.73	5.12	2.08	2.55	2.37	3.03
<i>Clausena anisata</i> (Willd.) Hook.f. ex Benth.	2.50	2.16	3.31	2.04	2.31	2.91	2.58
<i>Lonchocarpus cyanescens</i> (Schum. & Thonn.) Benth.	2.46	1.36	1.10	2.28	3.06	4.69	1.67
<i>Dichapetalum madagascariense</i> Poir.	2.45	2.04	1.60	2.90	3.60	2.26	1.97
<i>Pavetta corymbosa</i> (DC.) F.N. Williams	2.42	4.63	0.90	3.68	-	1.51	3.49
<i>Mallotus oppositifolia</i> (Geiseler) Müll.Arg.	2.32	5.43	2.21	1.52	2.10	-	2.65
<i>Griffonia simplicifolia</i> (DC.) Baill.	2.31	1.48	-	3.14	4.01	2.26	2.35
<i>Annona senegalensis</i> Pers.	2.29	1.24	0.70	0.76	3.58	1.51	6.14
<i>Allophylus africanus</i> P. Beauv.	2.27	1.48	2.70	2.16	1.86	3.34	2.12
<i>Psychotria calva</i> Hiern.	2.18	2.84	2.91	0.64	2.93	1.62	2.43
<i>Olex subscorpioides</i> Oliv.	2.12	4.38	2.01	1.76	1.42	2.16	0.61
<i>Clerodendron umbellatum</i> Ker Gawl.	2.05	1.60	6.83	0.88	1.86	2.37	-

TABLE 4: RELATIVE IMPORTANCE VALUE INDICES (IVI, %) OF THE 20 MOST DOMINANT SEEDLINGS IN THE TPFR, GHANA

Seedlings	Combined	BO	NK	AK	SA	AL	HH
	IVI	IVI	IVI	IVI	IVI	IVI	IVI
<i>Chromolaena odorata</i> (L.) R. King & H. Rob.	29.55	26.76	16.7	25.81	24.37	26.53	20.82
<i>Palisota hirsuta</i> (Thunb.) K. Schum. ex Engl.	7.46	5.16	5.95	15.22	10.39	3.38	7.37
<i>Costus affer</i> Ker Gawl.	6.04	2.48	4.71	13.81	10.17	4.72	5.03
<i>Hypselodelphys violacea</i> (Ridl.) Milne-Redh.	5.83	6.09	8.92	10.92	1.79	7.42	3.8
<i>Culcasia angolensis</i> Welw. ex Schott.	3.98	4.02	5.69	5.22	3.35	1.69	6.99
<i>Adenia lobata</i> (Jacq.) Engl.	3.89	2.48	2.85	3.17	9.05	3.04	4.48
<i>Panicum phragmitoides</i> Stapf	2.44	2.32	2.23	3.54	0.89	3.12	2.94
<i>Caesalpinia benthiana</i> (Baill.) Herend. & Zarucchi	2.30	1.14	-	-	6.15	1.86	5.44
<i>Andropogon gayanus</i> Kunth	2.22	2.36	3.68	-	--	2.53	2.36
<i>Tragia akwapimensis</i> Prain	2.22	5.16	1.24	-	--	4.56	2.04
<i>Chassalia kolly</i> (Schumach.) Hepper	2.08	1.34	3.10	1.49	7.71	-	-
<i>Abrus precatorius</i> L.	1.88	6.65	3.59	-	0.67	-	2.54
<i>Commelina Africana</i> L.	1.75	-	7.19	1.12	--	3.88	-
<i>Phayloopsis parviflora</i> Willd.	1.73	4.96	2.59	-	3.57	1.18	1.36
<i>Piper guineense</i> Schumach. & Thonn.	1.58	1.14	2.97	-	2.23	4.47	-
<i>Emilia coccinea</i> (Sims) G. Don	1.44	-	4.47	-	2.01	2.45	1.36
<i>Pennisetum purpureum</i> Schumach.	1.43	-	3.71	-	1.56	1.52	1.96
<i>Landolphia micrantha</i> (A. Chev.) Pichon	1.40	1.14	-	5.51	1.34	-	0.58
<i>Strophanthus sarmentosus</i> DC.	1.39	-	1.00	-	1.56	5.23	-
<i>Oplismenus burmannii</i> (Retz.) P. Beauv.	1.05	1.91	-	-	2.35	1.69	1.16

3. Species similarities and differences across the studied communities in the TPFR

The non-metric multidimensional scaling (NMDS) ordination analysis, based on species occurrences (i.e., presence or absence), showed a high degree of similarity in floristic composition among the studied communities (Fig. 4). This is evidenced in the pronounced overlap between the communities. In addition, permutation test of homogeneity of multivariate dispersion showed no significant differences ($p > 0.05$) in the variances among the studied communities. Moreover, the degree of similarity was highest between the BO and NK than between the AL and NK.

D. Elevation Effect on Species Distribution in the TPFR

Regression analysis generally indicated strong influence ($p < 0.05$) of elevation on the vegetation attributes of measured for trees across the studied communities (Table 5). The only exception to this was AK where no significant relations were observed between elevation and any of the vegetation attributes, and AL where Shannon diversity and evenness of trees were not strong associated with elevation. Basal area was also not correlated with elevation at NK and SA ($p > 0.05$). The saplings and seedlings generally exhibited a similar pattern. In terms of species distribution along the

elevation gradient, the five most dominant tree species in the study area (i.e., *C. pentandra*, *A. zygia*, *T. superba*, *A. toxicaria* and *C. gigantea*) exhibited mid-elevation peak distribution pattern (Fig. 5). Majority of the species were within the 300-399 m elevation range, whereas the 600-699 m range recorded the least number of individuals of these species as expected.

Fig. 4. Non-metric multidimensional scaling (NMDS) ordination of differences in floristic composition based on species occurrence (i.e., presence or absence) with respect to communities in the TPFR in Ghana. The following colours: red with broken lines, blue, gray, green, tomato, and dark green represents BO, NK, AK, SA, HH and AL respectively.

TABLE 5: CORRELATION OF VEGETATION ATTRIBUTES WITH COMMUNITIES IN THE TPFR IN GHANA

Attribute	BO		NK		AK		SA		HH		AL	
	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
Trees (DBH $\geq$ 10 cm, height = 1.3 m)												
Average Elevation (m a.s.l)												
Richness	0.48	0.008	0.50	0.005	0.08	0.672	0.59	0.001	0.64	0.00	0.41	0.024
Number of individuals	0.59	0.001	0.48	0.007	0.09	0.647	0.68	0.00	0.58	0.001	0.36	0.05
Mean Shannon diversity index	0.63	0.00	0.57	0.001	0.03	0.891	0.66	0.00	0.7	0.00	0.32	0.081
Mean Shannon evenness	0.25	0.176	0.46	0.011	0.05	0.797	0.49	0.007	0.55	0.002	0.32	0.089
Basal area (m ² /ha)	0.49	0.006	0.3	0.103	0.03	0.854	0.27	0.142	0.4	0.029	0.46	0.011
Saplings (DBH < 10 cm, height > 1.5 m)												
Richness	0.53	0.002	0.46	0.01	0.17	0.366	0.48	0.007	0.75	0	0.18	0.181
Number of individuals	0.63	0	0.39	0.033	0.06	0.75	0.56	0.001	0.62	0	0.43	0.017
Mean Shannon diversity index	0.28	0	0.43	0.017	0.1	0.582	0.47	0.009	0.56	0.001	0.36	0.054
Mean Shannon evenness	0.62	0	0.16	0.406	0.01	0.971	0.47	0.009	0.57	0.001	0.27	0.146
Seedlings (DBH < 3 cm, height < 1.5 m)												
Richness	0.6	0	0.1	0.604	0.32	0.085	0.84	0	0.6	0	0.15	0.44
Number of individuals	0.48	0.008	0.52	0.003	0.03	0.863	0.63	0	0.59	0.001	0.46	0.011
Mean Shannon diversity index	0.6	0	0.45	0.012	0.13	0.495	0.7	0	0.63	0	0.33	0.073
Mean Shannon evenness	0.73	0	0.54	0.002	0.12	0.536	0.26	0.159	0.71	0	0.28	0.131

Bold means regression was insignificant at 5% level.

Fig. 5. Species dominance by number of individuals with respect to elevation in the TPFR in Ghana.

IV. DISCUSSION

A. Plant Species Composition in the Togo Plateau Forest Reserve in Ghana

The overall plant diversity in the TPFR (281 in ca. 11.4 ha), was higher compared with studies from similar ecosystems in Ghana. For example, 176 woody plant species were recorded in ca. 1.9 ha in the Afadzato Community Forest Conservation Area and 142 plant species in a 2.4 ha area of the Atiwa Range Forest Reserve and 120 plant species in a 2 ha section of the Kade forest [22]-[20]. Other tropical forests, however, recorded a much higher species richness of over 300 per hectare in Ghana [26] and elsewhere [3], [5], [7], [12]. The high species diversity observed in the TPFR agrees with several studies that plateau ecosystems are one of the most ecologically complex and biologically rich ecosystems in the world [3]-[5] and that they provide a series of elevation gradients that drive the patterns of species composition and structure [8], [5], [15].

All the plant growth forms were identified in the 180 plots distributed throughout the TPFR in Ghana. The discovery of Leguminosae, Euphorbiaceae, Apocynaceae and Malvaceae as the most dominant plant families is not surprising as this is typical of tropical forests in Ghana [22], [26] and elsewhere [1], [17], [22]-[35]. These families are also the most important and well distributed across the six communities studied, an indication of their wide ecological amplitude and tolerance of diverse environmental conditions [17]. This result also suggests that tropical forests throughout the world showed much similarity at the family level [17], [23], and a prove of maturity as these families are generally represented by woody species [17], [23].

B. Species Diversity in the Togo Plateau Forest Reserve

Tree species richness and diameter class distribution in a defined ecologically hotspot gives a reliable instrument to indicate the diversity level [3]-[5]. The average Shannon-Weiner Index (H') (which is more sensitive to species richness) and evenness index for trees (3.99, 0.92) recorded

in the study were higher than studies from similar ecosystems in Ghana including the Kade forest (2.37, 0.86; [20]), Afadzato Community Forest Conservation Area (2.24, 0.85; [21]) and Atiwa forest (2.65, 0.84; [20]) and elsewhere (3.2, 0.58; [15]). The recorded values in this study were, however, lower than other similar studies including (4.05, 0.98; [23]) and (4.02, 0.96; [18]). Saplings and seedlings also follow a similar pattern in composition and structure. The high diversity of species recorded in the study suggests that the TPFR was not seriously disturbed by anthropogenic and ecological factors.

Across the study communities, Shannon-Weiner Index (H') and evenness index for trees varied (ranged from 4.14 at BO to 33.89 at AL) and (ranged from 1.00 at BO to 0.92 at AL), an indication of elevation gradient effect between the communities. Saplings and seedlings diversity and evenness index also followed a similar pattern. However, these results from the communities fall within the ranges of (2.00 to 4.86) and (0.21 to 1.00) reported in tropical forests in Ghana [20], [21], [22] and elsewhere [15], [17], [23]. These results showed that each community is very diverse, stable and well adapted [17], [23]. Probable causes for the local variations in species composition and structure among the communities include the geographical locations of these communities which somehow correspond with different elevations to the plateau (i.e., BO, NK occur in lower and gentle elevations, AK, SA in mid elevation and HH, AL in higher elevations with rocky and varied inclined slope areas). The BO and NK communities lie on lower elevations and generally receive lower solar radiation flux density resulting in lower evapotranspiration rates, lower daily maximal temperatures, and better soil types and thus, tend to be more humid, cooler and productive [1], [3], [4], [21], giving a higher habitat diversity [3], [6]. On the other hand, HH and AL lie on higher elevation and appeared to be receiving more solar energy resulting in low soil moisture content, higher transpiration rates and a reduction in plant growth [1], [3], [4], [21], giving a lower habitat diversity [3], [6].

The other factor accounting these slight differences in patterns of vegetation composition and structure among the communities in the TPFR could be utilization pressure [1]. The HH and AL communities have more traditional medicine practitioners, hence the rate of exploitation of plant materials from their portion of the plateau for traditional medicinal activities was higher than the other communities [19], [26]. These portions have also seen aggressive logging of *C. pentandra* and other woods to meet the timber needs of a recently established plywood factory in the area [1], [4], [19].

Basal area of trees (BA) provides a parameter that compare vegetation structure and quality [17]. The average basal area of 44.72 m² ha⁻¹ recorded in this study across the six communities was greater than that recorded in the Kade forest (30.85 m² ha⁻¹; [20]), Afadzato Community Forest Conservation Area (35.13 m² ha⁻¹; [21]), Atiwa forest (30.25 m² ha⁻¹; [19]) all of Ghana, the tropical deciduous forests of Northcentral Eastern Ghats, India (28.42 m² ha⁻¹; [23]), Deosai Plateau (30.27 m² ha⁻¹; [29]), Andean forests (33.90 m² ha⁻¹; [16]). Other studies have recorded a higher basal area than TPFR including dry evergreen forest of Kondapalli (Andhra Pradesh state, India) (47.17 m² ha⁻¹; [15]), Amaggal Reserve Forest (53.33 m² ha⁻¹; [28]) and

Mizoram-Manipur-Kachin rainforest (54.31 m² ha⁻¹; [17]). In general, the observed high species richness, Shannon diversity and basal area in the TPFR agrees with several reports that plateau ecosystems are species rich and very productive [1]-[5]. In the present study, the basal area of trees varied across the six communities (ranged from 57.10 m²/ha at BO to 33.10 m²/ha at AL). This variation may be attributed to varied environmental variables associated with elevation effect (i.e., wetter, or drier slopes, soil properties) [16]. However, the general high basal area values seen in all the communities gives an indication that the stand structure of the whole of the plateau is healthy [15].

C. Analysis of the Vegetation Structure of the TPFR

1. Diameter distribution of trees, saplings, and seedlings in the TPFR

The DBH evaluation reflects the evidence of disturbance and resource usage by species in forest ecosystems [15]. In the TPFR, many species (3499 individual's ha⁻¹) were present only as small individuals with diameters 10-100 cm DBH (Fig. 4 and 6), which was in accordance with the findings from several plateau forests [15], [17], [23] an indication that the plateau is harbouring a growing and healthy vegetation, and the site resources are being utilized to the maximum [17], [23]. The DBH, however, revealed a similar vegetation distribution across the study communities [16], [18].

2. The most important species in the TPFR

Importance Value Index (IVI) is computed for species or family with the aim of comparing their ecological significance in a given forest type [19], [21], [22]. A high IVI gives an indication that the species sociological structure in the community is high [15]. Plant species having similar IVI should automatically have similar stand composition and structure, environmental stress, site requirements, and comparable dynamics [13]. The leading dominant and ecologically most significant trees, saplings and the seedling on the landscape were *C. pentandra*, *A. zygia*, *A. camerunensis*, *S. krauseaena* respectively. These dominance of these species in the Togo Plateau landscape might be associated with their regeneration success, pathogen resistance, shade tolerance, and aggressive growth, optimal resource use and dispersal mechanism, while being the least preferred by browsing animals and disturbance stress [28]. Interestingly, all the communities had wide distribution of these species and may reflect their tolerance of wide ecological conditions [18].

3. Species similarities and differences across the studied communities in the TPFR

The results showed that the vegetation composition and structure was similar across all the study communities except AL which was quite distinct (Fig. 3, Table 5). The highest similarity was seen between BO and NK, suggesting that the two communities have similar vegetation requirements [18]. The distinct composition of AL from the rest of the communities may be due to its different altitude and associated environmental conditions which affect species growth and survival [18]. In fact, all the study plots from AL were located at higher altitudes than plots in the other communities.

D. Elevation Effect on Species Distribution in the TPFR

The six most important tree species listed on the landscape

were distributed along a broad range of elevation. These species have demonstrated an increase in composition and structure with altitude until mid-elevations and then decreases as expected in tropical forests [16]. As documented, rainfall and temperature decreased with elevation, meaning that forest at lower elevations were subjected to wetter and warmer conditions that favours plant growth [18]. In general, the results posit a strong influence of elevation gradient on vegetation attributes in the TPFRR.

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