Effect of Slope Gradient on Tree Species Richness in Kpatawee Forest, Liberia

ABSTRACT

Slope aspect is a critical environment factor influencing the abundance, distribution and diversity of vegetation. The objective of the study was to assess the tree species richness along different slope gradients in Kpatawee forest. Tree diameter was measured at breast height for species more than 5 cm in diameter and over 3 m in height. Tree species diversity was analyzed using Shannon diversity index (H'). Basal area (BA) which is the cross-sectional area of tree stems was measured through the diameter at breast height that is 1.3 m above ground level. Results showed that a total of 26 tree species were identified from the total sampling area (0.36 ha). The three richest families: Moraceae, Rutaceae and Euphorbiaceae appear to be well represented in the Kpatawee forest. These families become outnumbered in the herbaceous except for the Rutaceae family, which is ranked second. This is mainly due to their adaptation potential to wider agro-ecologies. Tree species richness was higher in the lower altitude. High species abundance was recorded in the lower altitude followed by the middle and upper. The lowest Shannon diversity index value (H' = 1.85) and the highest value (H' = 2.28) were recorded in the upper, and the lower altitudes, respectively. Despite their values, the biodiversity did not vary greatly from altitude to altitude. Diameter class distribution showed that more species were in the lower diameter classes and decreased gradually towards the higher classes. It is recommended that further studies on the entire Kpatawee forest is needed to fully understand the species richness in the forest.

1. INTRODUCTION

Topography is a critical environmental factor influencing the abundance, distribution, and diversity of vegetation. It regulates the movement of heat, light, water, and nutrients from the soil into different areas of the soil, creating microclimates with varying soil compositions and textures. Elevation, slope aspect, slope position, slope degree, and fluctuations are considered the main topographic factors that affect vegetation diversity and distribution patterns indirectly. However, there is large variability in the literature with regard to the effects of topographic factors on biodiversity patterns (Singh, 2018).

Some studies have concluded that the highest species diversity generally appeared in the intermediate position of the soil nutrient gradients, while others have insisted that it arose in the most fertile areas. Some studies also showed that species diversity decreased with increasing altitude, while others found that the moderate elevation occupied the highest species diversity due to the best hydrothermal conditions (Hu *et al.,* 2018).

Vegetation and biodiversity patterns in arid regions are influenced by environmental factors stronger than those in humid areas. Therefore, it would be more meaningful to study the environmental-vegetation relationships. Available water and nutrient capacity are considered the main environmental factors controlling vegetation distribution patterns. Slope aspect and slope position, however, in many aspects (e.g., sunlight, soil depth, soil moisture, and nutrients) determine the microclimate as well as ecological niches and are recognized as the main topographic factors of hilly regions (Elisabeth *et al.,* 2015).

Parameters pertaining to relief and its heterogeneity are frequently significant among the variables that have the capacity to affect the richness of tree species. Aspect regulates how much of the vegetation receives sunshine and how much moisture it retains. Slopes with higher irradiation, i.e., north and west in the Southern Hemisphere, have elevated temperatures and rates of evapotranspiration with a consequent reduction in soil moisture content and humidity, besides changes in chemical characteristics of the soil and in vegetation composition (Mi *et al.,* 2012).

Slope may also accelerate or attenuate irradiation effects on vegetation by influencing the loss of soil nutrients through erosion. Some studies have indicated that the physical and chemical characteristics of the soil, which vary as a function of the relief, show a direct relationship with the vegetation. It is said that relief and soil texture are important factors controlling drainage, water availability, moisture retention, permeability, and the amount of nutrients absorbed by the plants or lost through leaching (Singh, 2018).

Climate plays a significant role in altitudinal gradients, primarily because of temperature fluctuations. In tropical regions, there is strong evidence of relationships between relief features and tree species richness. Besides morphological characteristics, relief heterogeneity may influence vegetation diversity, richness, and composition in continuous as well as fragmented habitats. Slope gradients have a greater impact on species diversity in mountainous areas because of their steeper slopes (Zeng *et al.,* 2014).

The three primary topographic factors of height, slope aspect, and slope angle control the patterns and trends of vegetation in mountainous areas. The elevation is the most important one among the three, and these three factors together determine the microclimate and spatial distribution patterns of vegetation. Within one elevation, slope aspect, slope angle, and soil type are responsible for forest. Since there is more climate variation over shorter distances, changes in soil characteristics and vegetation patterns are more noticeable along the elevation gradient (Mendez-Toribio *et al.,* 2016).

Enhancing soil quality, reducing soil erosion, and improving slope soil shear strength are all made possible by increased vegetation cover, which makes ecosystem restoration easier. Variations in soil types are also a result of variations in microclimatic conditions, which impact soil stability and have an impact on soil development and processing. Additionally, it also affects the soil temperature, air temperature, and moisture content. Many studies have been conducted in temperate forests, temperate grasslands, arctic ecosystems, Mediterranean or tropical wet communities, and boreal forest ecosystems to examine the effects of topographical situations (slope aspect and slope angle) on vegetation composition and structure (Rai *et al.,* 2012).

A variety of plant species and the main living forms are referred to as vegetation, and these include grasses, forbs, trees, and shrubs. A forest is a vegetation unit that is so well-defined in its physiognomic and structural characteristics that it stands out from other vegetation units. Every forest group is associated with a feature that typically has a northern and a southern counterpart, with varying species compositions. A shift in patterns and trends in the composition and structure of the vegetation is formed by the two distinct characteristics. In montane forest ecosystems that exhibit elevation-based stratification, the highest impact of topography (slope angle, aspect, and elevation) typically takes place (Mi *et al.,* 2012).

In general, plant community ecologists are concerned with patterns of species response to environmental gradients and tend to adopt a continuum approach to vegetation with the assumption of continuous change in composition with position in the multi-dimensional environmental space. It is extensively reported that species richness extensively, and patterns of species richness are regarded as being determined by the interaction of disturbance with environmental gradients and competitive exclusion (Kubota *et al.,* 2004). The objective of this study was therefore to assess the tree species richness along different slope gradients in the study forest site and to evaluate the effect of the slope gradient on the tree species richness.

2. MATERIAL AND METHODS

2.1 Study site

The study was carried out in the Kpatawee rainforest. The study forest site is located in Suakoko, Bong County, in central Liberia. The forest area is selected owing to its home to many grasses, trees, and shrub species, which are said to be part of the remaining Upper Guinean rainforest. The study area lies at an altitude of 281 m above sea level and is located at 7.122470º latitude and -9.640607º longitude. Climatic variables such as temperature and rainfall pattern are largely tropical, with an annual average temperature of 25 °C and an annual average rainfall of 2013 mm distributed from May to October. The main soil types in the district include *latosols, lithosols, regosols,* and *alluvial* or swamp soils. Cassava, rice, and maize farming are the dominant crops grown in the area.

2.2 Experimental design and layout

Data on tree species richness and its characteristics was collected from three slope gradients: upper, middle, and lower. The position of the sampling site was determined after elevation data was collected from both the highest and lowest slope positions. A total of nine plots (three plots from each sampling position) with an area of 20 m x 20 m and a 10-meter interval between plots were established. After demarcating the plots, careful sampling was undertaken.

2.3 Vegetation data collection

The local influence of the slope gradient on the tree species richness is related to relief and hydrological dynamics, since soil properties are a direct consequence of these factors. Sampling was conducted at an undisturbed and continuous section of the forest to have a better understanding of the relationship between the relief features and the richness of Kpatawee rainforest tree communities. The tree sampling was performed on three sampling plots. According to Hu *et al.* (2018), all living trees with a diameter ≥ 5 cm at breast height (DBH) were recorded by species using the latest botanical classification. All tree species were assigned to their own families. A plant species identifier application was used, and the scientific names of plants were identified.

2.3.1 Tree Basal area calculation

Tree diameter was measured at breast height for species more than 5 cm in diameter and over 3 m in height. The diameter was measured using a diameter tape. According to Singh (2018), basal area (BA), which is the cross-sectional area of tree stems, was measured through the diameter at breast height, which is 1.3 m above ground level. It will help to measure the relative dominance (the degree of coverage of a species as an expression of the space it occupies) of a species in a forest. It was calculated as:

BA = $\pi DBH^{2}/^{4}$

Where BA = basal area (m^2), DBH = diameter at breast height (cm), π = 3.14

2.3.2 Tree species diversity indices

Tree species diversity was analyzed using the Shannon diversity index (H') as a measure of species abundance and richness to quantify the diversity of the woody species (Liu *et al.,* 2007). Therefore, both species abundance and species richness were considered in this index.

$$H' = -\sum_{i=1}^{s} pi\, ln\, pi$$

Where s equals the number of species and pi equals the ratio of individuals of species i divided by all individuals N of all species. The Shannon diversity index seldom rises above 4.5, usually falling between 1.5 and 3.5.

2.3.3 Dominance

Species dominance refers to the degree of coverage of a species as an expression of the space it occupies in a given area. Usually, dominance is expressed in terms of the basal area of the species. Two sets of dominance were calculated in this case: dominance (the sum of basal areas of the individuals in m^2/ha) and relative dominance, which is the percentage of the total basal area of a given species out of the total measured stem basal areas of all species (Zeng *et al.,* 2014).

Dominance = Total basal area/area sampled

Relative dominance = (Dominance of species A/total dominance of all species) * 100

2.4 Statistical analysis

Descriptive statistics such as minimum, maximum, mean, and standard deviation were performed to summarize the tree species richness and their characteristics along the slope gradient in the study forest. The MS Excel 2013 package was used to perform all the statistical analyses.

3. RESULTS AND DISCUSSION

3.1 Species richness and its characteristics

The whole dataset was made up of three slope gradients: upper, middle, and lower. The position of the sampling site was determined after elevation data was collected from both the highest and lowest slope positions. A total of nine plots (three plots from each sampling position) with an area of 20 m x 20 m and a 100-meter interval between plots were established. A total of 26 tree species were collected.

3.2 Species richness

The three richest families in the study area were *Moraceae*, *Rutaceae,*and*Euphorbiaceae,* which appear to be well represented in the forest. In the herbaceous, these groups become outnumbered, with the exception of the *Rutaceae* family, which comes in second. In the studied area, these findings suggested that 10% of all species were from the *Rutaceae*family, despite the presence of some tree ferns in the woody (tree and shrub) families.

3.3 Relationship between species richness and slope gradients

The trees under study determined how slope gradients and species richness interacted (Table 1). Species richness decreases with increasing slope gradients for woody species (trees and shrubs).

Table 1. Abundance, species richness and Shannon index of the three slope positions

Slope	Abundance	Species richness	Shannon diversity index
Lower	155	10	2.28
Middle	96	9	2.10
Upper	36	7	1.85

Results in Table 1 indicate that a high number of tree species were recorded on the lower slope. However, it was on the upper slope, which indicated low species richness. The biodiversity did not vary greatly from slope to slope in the study area. A low Shannon diversity index value was obtained in the upper slope position (H' =1.85), whereas the highest value was obtained in the same aspect in the lower slope position (H' = 2.28). This study is supported by Molla and Asfaw (2014), who reported 43 different woody species in natural forests. Shannon's diversity index of tree species in natural forests (H' = 2.76).

The Shannon diversity index ranges typically from 1.5 to 3.5 and rarely reaches 4.5 (Mueller-Domboisand Ellenberg, 1974). Recently, various studies were conducted, especially on plants, to assess how the species richness of different trees is influenced by slope gradients (Zhang *et al.,* 2012). In some rare cases, researchers found the same relationship between slope gradients and species richness (unimodal or monotonic) for all the studied trees, but, more often, this relationship differs between the trees.

Some of these works have been performed on small slope gradients, and most of them in temperate climates. Here, this study showed that, in wide slope gradients in tropical Africa, the relationship between species richness and slope gradients varies from one vegetation life form to another. In a tropical African mountain, the species richness of trees and shrubs is negatively linked with slope gradients between 810 and 2760 masl, showing a monotonic decline with rising slope gradients. Ecophysiological limitations at higher slopes, such as temperature drops or CO2 pressure, are undoubtedly to blame for this decline in species richness. These limitations may have an impact on photosynthetic capacity, net primary productivity, and the maintenance of living structures (Kubota *et al.,* 2004).

It was shown that there was a substantial correlation between the species richness and slope gradients of 15 families (Table 2).

- For the families Moraceae, Rutaceae, and Euphorbiaceae, both species richness and abundance decline with rising slope gradients.
- As slope gradients increase, the number of individuals in the Lauraceae and Phytocaccaceae groups rises but the number of species falls.
- For the other families, increased slope gradients cause either an increase or decrease in the number of species or individuals.

The species richness of a family does not always follow the pattern set by the forest that the species is found in. Some families followed the general forest trend, while others displayed a totally different trend (Table 2). These various trends suggest the existence of family-specific sensitivity to changes driven by slope gradients, a variety of eco-physiological properties of each family, and family trait-based responses (William *et al*., 2017).

For trees and shrubs, the amount of families decreasing in species richness was higher than that of families increasing along the slope gradients, but the opposite is observed in the herbaceous (Table 2). For example, woody families such as *Myricaceae, Ericaceae, Monimiaceae, Myrsinaceae, Theaceae, and Podocarpacea*e (Table 2) are positively correlated with slope gradients (Augusto *et al*., 2017). This is also partially the case for *Rubiaceae*, which shows in both woody areas a slight increase in species as well as an increase in abundance following slope gradients, especially in the shrub. One of the most prevalent families in the understory of tropical lowland forests is*Rubiaceae,* but in highland forests above 2000 meters above sea level, its significance seems to be much greater (Xuluc-Tolosa *et al*., 2003).

Families such as *Phyllanthaceae* and *Pandanaceae,* which gather many species from the *Uapaca* and *Pandanus genus*, characteristics of riverside forests that decrease with increasing slope gradients. Megathermal families that are typical of lowland tropical rainforests are the *Fabaceae, Meliaceae*, and *Annonaceae* families. It is acknowledged that the *Fabaceae* family is among the wealthiest in the lowlands of Africa (Yadvinder *et al*., 2002).

Table 2: Botanical name, vernacular name, and their family of the dominant species in the three slope positions in Kpatawee Forest

Slope	Species name	DBH (cm)	BA (m^2)	RD (%)	Abundance	spices diversity
Lower	*Ormosia coccinea*	2.23	0.0004	0.54	12	0.20
Lower	*Solanum Lycocarpom*	1.91	0.0003	0.40	17	0.24
Lower	*Pittosporum viridiflorum*	2.55	0.0005	0.71	19	0.26
Lower	*Siparunaguianensis*	2.23	0.0004	0.54	22	0.28
Lower	*Petiveriaalliaccea*	2.55	0.0005	0.71	10	0.18
Lower	*Ficus benjamina*	2.86	0.0006	0.89	14	0.22
Lower	*Excoecariacochinchinensis*	2.55	0.0005	0.71	22	0.28
Lower	*Tovomitabrasiliensis*	3.18	0.0008	1.10	13	0.21
Lower	*Apodytesdimidiata*	2.23	0.0004	0.54	15	0.22
Lower	*Theobroma cacao*	4.46	0.0016	2.17	11	0.19
Middle	*Carpinus betulus*	3.50	0.0010	1.34	16	0.30
Middle	*anaxagoreaAnnonaceae*	1.91	0.0003	0.40	10	0.24
Middle	*Genus(Hoya)*	7.32	0.0042	5.84	9	0.23
Middle	*Thebromacacaol*	2.55	0.0005	0.71	13	0.27
Middle	*Citrus sinensis*	2.55	0.0005	0.71	8	0.21
Middle	*Bursera burseraceae*	2.86	0.0006	0.89	3	0.11
Middle	*Plinia cauliflora*	2.55	0.0005	0.71	19	0.32
Middle	*Cridoscolusaconitifolius*	12.73	0.0127	17.68	12	0.26
Middle	*Ficus benjamina*	9.55	0.0072	9.94	6	0.18
Upper	*Goupia glabra*	6.37	0.0032	4.42	7	0.32
Upper	*Tovomitabrasiliensis*	9.55	0.0072	9.94	6	0.30

Upper	*Ficus benjamina*	7.96	0.0050	6.91	5	0.27
Upper	*Sapiumellipticum*	2.86	0.0006	0.89	3	0.21
Upper	*Laurus nobilis*	2.23	0.0004	0.54	2	0.16
Upper	*Maesa lanceolata*	2.86	0.0006	0.89	9	0.35
Upper	*Anaxagoras dolichocarpa*	16.55	0.0215	29.88	4	0.25

Slope gradients in the herbaceous zone drastically reduce the number of species belonging to the *Zingiberaceae* and *Marantaceae* families; these species are primarily limited to lower slope gradients found in clearings, understory areas, and riverbanks. According to Grinand et al. (2017), these groups are primarily found in the tropics and are likewise megathermal. In other instances, two factors, their tendency toward microthermality and their desire for light, may be connected to the growing trend of species richness within several families.

It's possible that forests with higher slope gradients benefit from the increased light availability. For instance, *Asteraceae* species and several fern species from families like *Aspleniaceae*, *Dennstaedtiaceae*, *Lycopodiaceae*, etc. were more diversified in tropical highlands and temperate settings but were rarely found at lower slope gradients (frequently in lit areas). The structure of their daisy-like blossoms may also account for their strong occurrence in mountains (Takimoto et al., 2009), which would make it easier for mountain breezes to scatter them.

Table 3: Summary of the structural characteristics along slope gradient of forest

structure parameters	Upper slope			Middle slope			Lower slope		
	DBH (m)	BA (m²)	RD (%)	DBH (m)	BA (m²)	RD (%)	DBH (m)	BA (m²)	RD (%)
Mean	6.91	0.0055	3.93	5.06	0.0031	4.25	2.67	0.0006	0.83
Std Dev	1.93	0.0028	1.58	1.29	0.0014	2	0.23	0.0001	0.16
Min	2.23	0.0004	0.54	1.91	0.0003	0.4	1.91	0.0003	0.4
Max	16.55	0.022	9.94	12.73	0.013	17.68	4.46	0.002	2.17

Diameter at breast height (DBH), basal area (BA), relative dominance (RD)

There were more individuals in the diameter size; all individuals were distributed differently among the various DBHs (Table 3) along the slope gradient. According to Worku et al. (2012), the diameter at breast height distribution generally indicated that the species were more prevalent on the upper slope and gradually reduced towards the lower slope. Different patterns in the slope gradient were produced by the density distributions of some tree species in different diameter classes. *Sapiumellipticum* produced the highest DBH of trees in the middle slope (> 90 cm), whereas *Ficus sycomorus* species recorded the highest DBH (< 10 cm).

According to Bajigo and Tadesse (2015), the degree of covering of a tree species as a representation of the space it occupies in a forest is known as its relative dominance. In Table 2, RDs for every species of tree are listed. In the higher slope, *Anaxagoras dolichocarpa* (29.88%), *Cridoscolusaconitifolius* (17.68%), *Tovomitabrasiliensis* (upper slope), and *Ficus benjamina* (9.94%) were the tree species with the highest RD. There was another similar relative dominance.

4. CONCLUSION

In this study, the richness and abundance of tree species were examined. The entire sampling area (0.36 hectare) yielded the identification of 26 different tree species. The three wealthiest families, the *Moraceae*, *Rutaceae*, and *Euphorbiaceae*, which seem to be well-represented in the woods, are represented in all analyzed cases by decreasing species richness. In the herbaceous, these groups become outnumbered, with the exception of the *Rutaceae* family, which comes in second. Their capacity to adapt to larger agroecologies is primarily to blame for this. Lower altitudes showed a higher species richness of trees. The lower altitude showed the highest species abundance, followed by the medium and above elevations. In the upper and lower altitudes, respectively, the lowest Shannon diversity index value (H' = 1.85) and the highest value (H' = 2.28) were found. The biodiversity did not significantly change between altitudes despite their values. The distribution of diameter classes revealed that fewer species were found in the higher diameter classes, with a gradual decline in the lower diameter classes.

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