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PATTERNS OF TROPICAL TREE SPECIES RICHNESS ALONG ELEVATIONAL GRADIENTS OF MOUNTAIN AFADJATO, GHANA

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Abstract

This paper evaluates the effect of altitude on tree species richness, diversity and tree abundance to assess the responses of tree species to environmental changes. The highest mountain in Ghana, Afadjato, was categorized into three namely, lower elevation (200m -400m ASL), middle elevation (400m-600m ASL) and from 600m ASL and above the mountain as upper elevation. On five transects running from the bottom to the top of the mountain, two 20m by 20m squared plots were laid in each category on any 20m rise in altitude along the gradient of the mountain. All trees greater than 5cm in diameter at 1.3m above ground were identified and measured. The species richness, basal areas of trees and diversity differed in all the three levels of elevation. Tree abundance was found to decrease with increasing altitude. Recommendations have been made for future studies to establish the various relationships between the factors contributing to the variations along the elevation gradient.

Keywords: Elevation, Ghana, Mountain, Species richness, Tropical trees.

Özet

Bu çalışma ile ağaç türlerinin çevresel değişimlere gösterdiği tepkiyi ortaya koymak maksadıyla yükseltinin ağaç türü zenginliği, tür çeşitliliği ve rastlanma sıklığı üzerine etkileri araştırılmıştır. Gana'nın en yüksek dağı olan Afadjato dağı denizden yüksekliklerine göre 200-400 m, 400-600 m ve 600 m'nin üzeri olmak üzere üç yükselti basamağına ayrılmıştır. Kütlenin eteklerinden zirvesine doğru 5 kesit alınmış ve her bir 20 m yükselti artışında her bir kesitten 20 x 20 m^2'lik 2'şer tane örnek alan alınmıştır. Göğüs yüksekliği çapı 5 cm'nin üzerinde olan bütün ağaçlar teşhis edilmiş ve ölçümleri alınmıştır. Ağaç türü zenginliği, göğüs yüzeyi alanı ve tür çeşitliliği bütün yükselti kademelerinde farklı bulunmuştur. Ağaçların rastlanma sıklığının yükselti arttıkça azaldığı tespit edilmiştir. Çalışmamızdan çıkarılan sonuçlara göre yükselti ile gerçekleşen değişimlerin daha iyi anlaşılması için daha farklı değişkenlerin denendiği çalışmaların yapılması gerektiği anlaşılmaktadır.

Anahtar kelimeler: Yükselti, Ghana, Dağ, Tür zenginliği, Tropikal ağaç türleri.

INTRODUCTION

Mountain ecosystems provide a vast array of goods and services to humanity, both to people living in the mountains and to people living outside mountains (MA, 2005). Mountains represent an enormous compression of life zones with a wide diversity of climate combined with local differences owing to geomorphological, edaphic and plant cover features have given rise to a range of micro-climate which has become habitat for different species which adapt and making them their specific niches. According to Heywood (1995), about 3% of the terrestrial surface of the earth is covered by high mountain ecosystems, where about 4% of the earth's flora is found. Mountain ecosystems provide a fundamental characteristic to the drastic change in vegetation and in climate from the base to the top of mountain (Yu, 2004). Elevation gradients create varied climates, along with resultant soil differentiation; promote the diversification of plant and animal species (Brown, 2001; Lomolino, 2001). Many studies have investigated species richness along elevation gradient across habitats and taxa (Rahbek, 1995; Austrheim, 2002; Vetaas and Gerytnes, 2002; Sanders *et al*., 2003) and as part of efforts to understand ecosystem effects on biodiversity and conservation of biodiversity (Vetaas and Gerytnes, 2002).

Strong local segregation occurs between similar species, such as the masked shrew (*Sorex cinereus*) and the southeastern shrew (*Sorex longirostris*) (Pagels and Handley, 1989; Ford *et al*., 2001). Species distribution variation along the gradient has been demonstrated by early forestry researchers on tree distribution such as Whitteker (1956) and relied on the assumption that increasing elevation is analogous to decreasing moisture. However, the distribution response of species across an elevation gradient has been found to be related to the latitudinal location of the study site. For example, *Acer pensylvanicum* occurs at high elevations (800+m) in west Virginia and Virginia, but occurs at middle elevations (400m-600m) in North Carolina and Tennessee (Whittaker, 1956; Mills and Stephenson, 1999). But *Acer rubrum* shows a reversal of the pattern occurring at high elevations (800+m) in South Carolina, but low to middle (200 to 600m) elevations in areas of north of South Carolina (Whitney and Johnson, 1984; Harrison *et al*., 1989; Davis *et al*., 2003). However, some species show little or no variation in their elevation distribution across a geographic area. Further, elevation has been found to be merely a surrogate for a suite of biotic and abiotic factors that influence species richness (Rahbek, 1995).

The intention of this research is to establish the variations that occur in the community of tree species along the gradient of mountain ecosystems. The question is at what magnitude of altitude can tree species change in richness, diversity and in abundance? Therefore the main goal of the study was to assess the variations in distribution of trees along different elevations on Afadjato mountain located in the southeast of Ghana.

Materials and Methods

Study Area

Mountain Afadjato is part of Akwapim-Togo range which constitutes the highest hill in Ghana with the Afadjato itself being the highest mountain in Ghana at 885m above sea level which runs in the northeast and southwest direction between the Volta River and the Ghana-Togo border (Ntiamoah-Baidu *et al*., 2001) (Figure 1). The hill lies within longitude 0^{o}15'E and 0^{o}45' E and latitude 6^{o} 45' N and 7^{o} 15' N and covers an area of 1172km^2 (Owusu, 2010). The mountain is endowed with two major waterfalls - Wli and Tagbo waterfalls at the northern and southern borders, respectively (Ntiamoah-Baidu *et al*., 2001). Mountain Afadjato has been declared as an Important Bird Area (IBA) by Fispool and Evans (2001).

Climate and Vegetation

The annual rainfall total ranges between 1100mm and 1500mm, averaging 1300mm. The rainfall pattern is bimodal with two distinct rainy seasons. The major rains start from April through to July while the minor season covers the period from September through November. Occasionally the Afadjato area bimodal pattern gives way to continuous rain from April through to November. On the average, the major season receives about 43% of the total annual rainfall as compared to about 40% for the minor season. Comparative figures however establish a greater reliability of the rain both in quantity and distribution during the minor season than the major season.

The Afadjato area falls within the Forest-Savanna transitional ecological zone of Ghana, with the forest part at its southern and eastern sector. The vegetation of the transitional zone is considered to have developed from the forest. The eastern highlands are clothed with high forest (Hohoe Municipal Assembly, 2006).

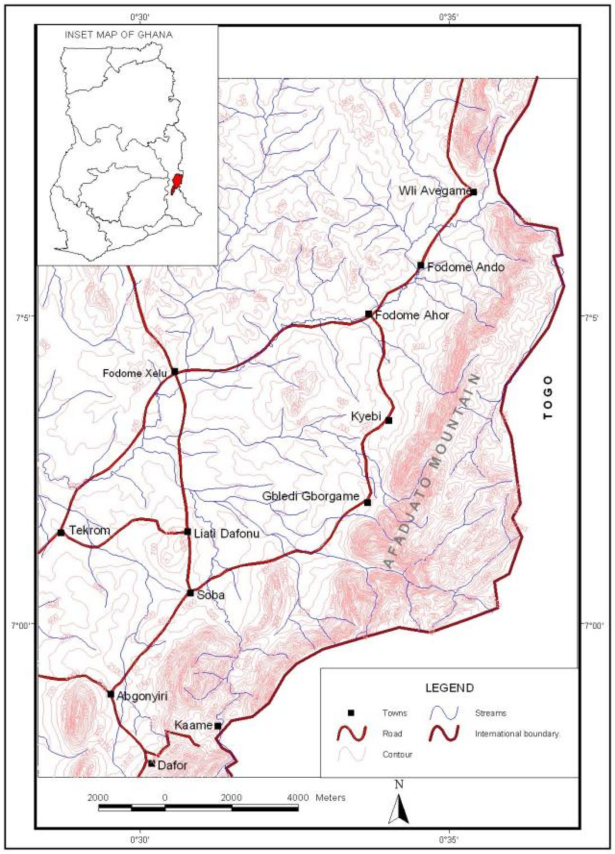

Figure 1: Map of study area showing the location of the mountain

Sampling Procedure

Transects were established perpendicular to the contours of the ridge and along transects, sample plots were established. The total length of transects were divided into three categories in accordance with the following elevation classes: lower elevation (200-400m), middle elevation (400-600m) and upper elevation (600m and above). Subsequently, five transects were established along five major entry routes to the summit of the mountain. At every elevation class on a transect, two sample plots in the form of quadrants with the dimension of 20m X 20m were established at every 20m rise in altitude and not less than 100m horizontal distance from each other. All tree species greater than 5cm in diameter were identified and measured at 1.3m above ground.

Data Analysis

Minitab 4.0 was used to perform several analyses of variance of the three levels along the mountain. The species richness was first examined. The total area covered by trees within each plot was calculated by finding the basal area of each tree and adding all the basal areas of trees within the plot by formular 1. The basal areas of trees in all the three levels along the mountain were examined.

Basal Area= $\frac{\pi D^2}{4}$---------------------------Formular 1

The Shannon index of diversity was determined with PAST software to ascertain the biodiversity variations along the mountain gradient. The total number of trees in each plot of the three levels of the elevations were tabulated and compared for significance.

RESULTS

Distribution of Tree Species Richness

In all 10 plots were established and enumerated at each of the levels of elevation. The mean species richness found at the lower elevation was 9.7 (SD=4.547), middle elevation was 8.4 (SD=2.633) and upper elevation was 6.1 (SD=0.738). The analysis of variance indicated a significant difference between tree species richness occurring at the three levels along the mountain (F= 3.54, P= 0.043). Comparing the richness of any two levels, the number of trees enumerated in the lower elevation did not differ from that of the middle elevation (F=0.61. p=0.44) but were higher than the upper elevation (F=6.11, p=0.024). However, the richness of trees at the middle and upper elevations also differed significantly (F=7.07, p=0.016) as shown in Table 1. Furthermore, from Figure 2, it could be deduced that the box for species richness of the upper elevation is comparatively shorter, which suggests that the overall species richness among the 10 plots has high level of agreement with each other. On the other hand, the boxes for the lower and the middle elevations were comparatively taller. This suggests that the richness among the 10 plots was wider from each other or low level of agreement with each other.

Similarly, the basal areas of trees in the plots of lower, middle and upper elevations differ significantly from each other (F=7.49, p=0.003). The basal area for the tree at lower elevation was larger than upper elevation (F=12.09, p=0.003) but did not differ from that of the middle elevation (F=2.59, p=0.125). The basal areas between the middle level trees also differed from the basal areas of trees in the upper level (F=13.42, p=0.002). The composition of species for each elevational belt is shown in Table 2.

Table 1: Means (± 95% confidence intervals) of tree species richness at three different elevations at Afadjato Mountain, Ghana

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                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level   N  Mean   StDev  ---------+---------+---------+---------+
Lower   10 9.700  4.547               (---------*--------)
Middle  10 8.400  2.633          (---------*---------)
Upper   10 6.100  0.738  (---------*--------)
                  ---------+---------+---------+---------+
                          6.0       8.0      10.0      12.0
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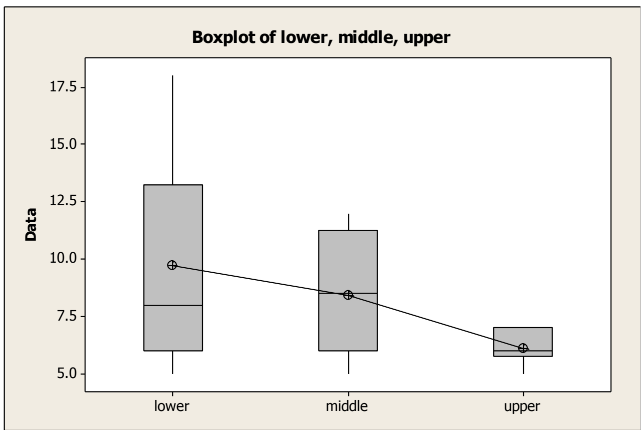

Figure 2: Boxplots of means of tree species richness of lower, middle and upper elevations of Mountain Afadjato.

Tree Diversity

The Shannon index of diversity indicated that the diversity of trees at the lower level of the mountain was 2.95 at 95% Confidence Limit (95% CL) of (2.78-3.16), middle level was 2.42 (95%CL=2.76-3.17) and at the upper level the diversity was 0.91(95%CL=1.78-2.46). The diversity at the lower elevation was higher i.e. more diverse than the middle elevation (t=3.27, p=0.001) and upper elevation (t= -9.41, $p=5.98^{-10}$). Similarly, diversity of the middle and upper differed significantly (t=6.53, $p=8.663^{-10}$) (Table 1).

Table 2: Tree species along the various elevation points

Elevation level	Species
Lower level	*Albizia adanthifolia, Albizia zygia, Alstonia bonei, Antocleista nobilis, Ceiba pentandra, Cola caricifolia, Cola gigantean, Cordia millenii, Dacryodes klaineana, Dalbergia latifolia, Dialium guineense, Erythrophleum ivorense, Ficus sur, Khaya senegalensis, Lecaniodiscus capaniodes, Lonchocarpus sericeus, Lophira lanceolata, Magaitaria discoidea, Milicia excels, Morus mesozygia, Nesorgordonia papaverifera, Spondias mombus, Terminelia avicinoides, Terminelia superba, Tetrapleura tetraptera, Trichilia monadelpha, Trilepisium madagascariense, Triplochiton scleroxylon*
Middle level	*Afzelia bella, Albizia adanthifolia, Anogeissus leiocarpus, Antocleista nobilis, Cola caricifolia, Dacryodes klaineana, Dalbergia latifolia, Daniella oriverii, Erythrophleum ivorense, Holarrhena floribunda, Lecaniodiscus capaniodes, Lophira lanceolata, Parkia biglobosa*, *Terminelia avicinoides*
Upper level	*Combrentum nigricans, Daniella oriverii, Gardenia aqualla, Lophira lanceolata, Piliostigma thonningii*

Relationship between tree Abundance and Altitude

A negative relationship emerged when the abundance of trees were related with the altitude through regression analysis. This suggests that as the altitude increased the number of trees decreased significantly (P=0.000); though the Adjusted R^2 was 0.198. Thus 19.8% changes in the number of trees were explained by changes in altitude (Table 2).

Table 3: Regression Results

Predictor	Coefficient	Std Error	T ratio	Probability
Constant	12.639	1.689	7.48	0.000
Altitude	-0.008966	0.003136	-2.86	0.008

Adj R^2=0.198

DISCUSSIONS AND RECOMMENDATION

Tree species richness was found to be varied along the mountain when traversing from lower elevation through the middle to the top. This result can be related to findings by Brown (2001) and Lomolino (2001) which revealed diverse plant and animal species along elevation gradient on mountainous ecosystem as well as varied climate and soil differentiation. The study also confirms works by (Rahbek, 1995; Austrheim, 2002; Vetaas and Gerytnes 2002) where species richness along elevation gradient across habitats has been established. It can also be deduced from this study that the habits of the species as one travels from lower elevation to upper elevation changes from species of forest ecosystem to that of savannah ecosystem. (The middle elevation level comprise species of both forest and savannah ecosystem) (Table 2). These changes may be attributed to two main factors: firstly, the water availability is high and decreases as the altitude increases and secondly, the soil nutrient contents might be high at the lower and the middle elevations than the top elevation. This is because the top soil nutrients at the top elevation might have suffered from erosion and be deposited on the lower elevation. This might also explain why the tree richness was poor at the top elevation and rich at the lower elevation.

A similar trend emerged with the sizes of the trees where the basal areas of the trees at the lower elevation were also larger than those of trees found at the higher elevations.

The reason for the low species richness and poor basal area of trees at the middle to top site could be due to the steepness of the mountain side and associated leaching of nutrients which will make it hard for trees to grow under such conditions.

For future research, the study recommends that a lot of data should be collected to unveil more precise changes between sites. Tree height could also be measured so that tree growth measurements would not only rely on lateral growth. Soil organic matter and moisture could also be measured to help one understand the reasons for differences in richness, growth and abundance of trees along the gradient of the mountain.

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