

Topographic influence on *Terminalia* species diversity in Oluwa forest reserve, Ondo State (Nigeria)

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Abstract

Most natural forests throughout the world have been destroyed and converted to human land uses to meet the ever growing demands for resources while the remaining forest landscapes consequently have a mosaic of human-modified land areas such as urban, agricultural, and plantation lands. Forest and forest products provide myriad of economic, financial and health importance. The threat to the rainforest compelled the establishment of forest reserves with the introduction of exotic tree species. The Oluwa forest is located between latitudes 6°37' and 7°20' north and longitudes 4°27' and 5°05' east in Ondo state, Nigeria. Species richness and abundance data are crucial for conservation priority setting, and long-term vegetation monitoring. Few studies have been carried out on the composition of Terminalia spp, diversity and richness in the institutional-based landuse. The aim of this work is to analyze the influence of topography on Terminalia species diversity for conservation purpose. Complete enumeration of the Natural forest was carried out to determine the varieties of Terminalia species in the study site. In all, two variety, Terminalia, superba and Terminalia ivorensis were identified. GPS coordinate their locations was overlaid on Elevation, Slope, Aspect and Hillshad. The area with low elevation, and low slope, high hillshade, and the west aspect showed maximum species abundance. The Shannon diversity index of Terminalia species was calculated and the result implies that the diversity/abundance is low in the study site. It was observed that the spatial distribution and relative abundance of these species was influenced by topographic factors. Despite the limited range of altitudinal variation (399 m), species richness increases with elevation. This work has provided evidence of variability in Terminalia species composition, richness and diversity across the topographic gradient. The information could be crucial for monitoring and providing conservative measure for management of species sustainability. A future study would be required to isolate proximate factors of tree species distribution.

Keywords: Influence, topography, Terminalia species diversity, Oluwa Forest reserve, Nigeria.

1. Introduction

Ascertaining the relative contribution of the factors influencing the structure and diversity of ecological communities along environmental gradients has been a persistent theme in ecology (Liu *et al.*, 2014; Zhang *et al.*, 2013), and is crucial for informed vegetation restoration and biodiversity protection practices such as selection of forest degraded areas. In order to solve this scientific problem, numerous mechanisms of species coexistence were proposed by ecologists, including the niche theory, neutral theory, and negative density dependence mechanisms (Jia *et al.*, 2015).

Plant ecologists have been successful in defining the variations in species composition of communities along environmental gradients at different spatial scales. At regional and global scales, plant community responses are well related to climate factors (Liu *et al.*, 2007; Bami *et al.*, 2012; Woodward & Williams, 1987), whereas at local or plot scales, topographic and edaphic factors play a critical role in controlling community structure and species distribution (Katabuchi *et al.*, 2012; Baldeck *et al.*, 2013; Laurance *et al.*, 2010; Odgaard *et al.*, 2014; Fadrique et Homeier, 2016).

According to FAO (2001), the annual deforestation rate in Africa is about twice as high as the global rate (0.3 versus 0.7%). Bio-geographers have long-cherished the passion in spatial and temporal distribution of plant diversity (Whittaker *et al.*, 2005) especially the measurement of the patterns of species occurrence (Gillespie *et al.*, 2008). The importance of measuring species diversity as an indicator of ecosystem health has been recognized by major initiatives worldwide (Skidmore *et al.*, 2015). Therefore, environmental variables are important not only in verifying plant community structure and species distribution variability at a spatial scale but also in providing insight into the environmental requirements of the tree species needed for successful ecological restoration and biodiversity protection (Zhang *et al.*, 2013; Toledo *et al.*, 2012; Xiu *et al.*, 2012). Although the effects of topographical and edaphic factors on community traits, diversity, and species distribution have been reported in the Lower Lancang River Basin (LLRB) (Li *et al.*, 2012a; Li *et al.*, 2012b; Zhu *et al.*, 2004; Xu *et al.*, 2015), most such studies either focused on tropical forests or were conducted near the river banks of cascading dams.

The Genus *Terminalia* belongs to family Combretaceae comprising of nearly 200 species of trees distributed throughout the humid, semi-humid, tropical and subtropical regions of the world. Nearly 24 species of *Terminalia* have been reported from various states/union Territories of India (Srivastav, 2003). About fifty of these are native to Africa and distributed throughout the sub-saharan region (Lebrun and Stork, 1991). Based on both their functional uses and distribution in Africa, the most important are *Terminalia ivorensis*, *Terminalia chebula*, and *Terminalia superba* and *Terminalia catappa* in West and Central Africa and *Terminalia prunioides* and *T. sericea* in Southern Africa (Schmidt *et al.*, 2002; Lawes *et al.*, 2004). *Terminalia* trees are planted in several countries in the tropics as a source of high quality solid timber for fine carpentry, joinery, building, flooring and plywood manufacture (Schmidt *et al.*, 2002; Smith *et al.*, 2004). *Terminalia ivorensis* and *T. superba*, especially, form an important component of the forestry industries in many countries (Anonymous,

1997). Furthermore *Terminalia* has various uses in pharmaceutical, indigenous medicine therapies, silk and other chemical industries (Srivastava, 2000).

The natural vegetation of Oluwa forest reserve with the exception of the areas devoted to forest reserve has now been reduced to secondary regrowth, forest thickets and fallow regrowth at varying stages of development or replaced by perennial and annual crops (Osunade, 1991). These perennial crops include cocoa, kola and citrus (Oluwagbenga, 2014).

2. Study area characteristics

2.1. Geographical description

The study areas Oluwa forest reserve in south western Nigeria is one of the two largest industrial plantation sites in Nigeria. The forest covers an area of 87,816 ha (FORMECU, 1999) and it is located approximately between latitudes 6°37' and 7°20' north and longitudes 4°27' and 5°05' east (figure 1).

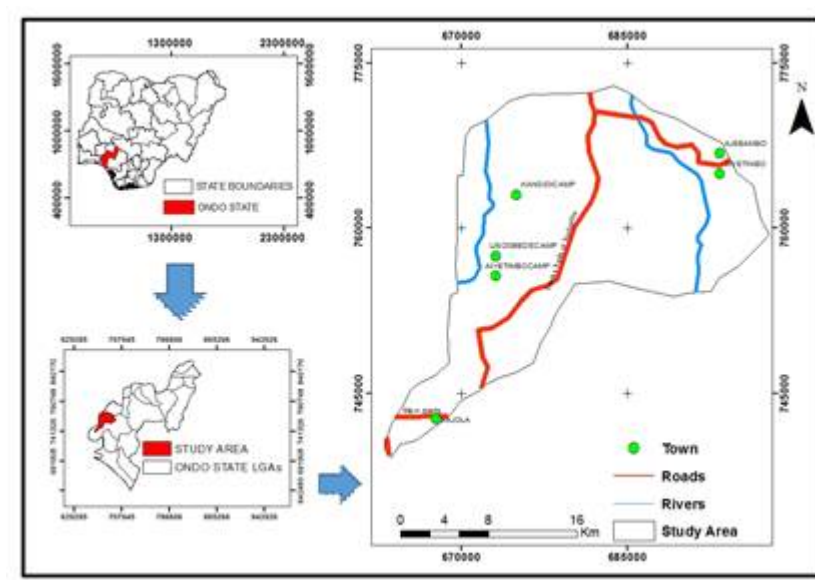


Figure 1. Map showing location of Oluwa Forest Reserve

2.2. Biophysical characteristics

2.2.1. Climate and Rainfall

The climate of Oluwa forest is tropical, comprising of distinct rainy and dry seasons and characterized by high mean annual temperature (about 26^oC) and well distributed high annual rainfall (1700–2200 mm). Rainy season covers a period of 9 months (March–November) annually, but intensive rainfall starts from April to October and peaks in June/July and/or September. Dry season lasts 3 months (December–February), but there could be little rains during the dry months. Annual average daily relative humidity is about 80% in the forest reserves (Onyekwelu, 2001).

2.2.2. Soil texture

The soils of Oluwa is Alfisols. It is an example of the variety normally found in the intensively weathered areas of basement complex formations in the tropical rainforest zone of south western Nigeria. The majority of the soils are representative of soils in the Ondo Association, which comprises of well-drained, mature, red, stony and gravelly soils in the upper parts of the sequence, grading into the hill wash overlying original parent material or hard-pan layers in the valley bottom (Smyth and Montgomery, 1962). The texture of the topsoil in both reserves is sandy loam, which gradually becomes heavier as one dig deeper into the soil. The sub-soil consists of clay with gravel occurring at 30–60 cm depths.

2.2.3. Vegetation

The natural vegetation of the area is the tropical rainforest characterized by emergent with multiple canopies and lianas. Some of the most commonly found trees in the area include *Melicia excelsa*, *Azelia bipindensis*, *Antiaris africana*, *Brachystegia nigerica*, *Lophira alata*, *Lovoa trichiliodes*, *Terminalia ivorensis*, *T. superba*, *Triplochiton scleroxylon*, etc.

2.2.4. Topography and Slope

Slope and topography described the shape and relief of the land. Topography is a measurement of elevation while slope is the percentage change in elevation over a certain distance (Moustafa and Zayed, 1996). The topography of the study area is part of the western plains and ranges of Nigeria with much of it lying approximately between 300 and 600 metres above the sea level (Iloje, 1981). So the slope of the study area is remarkably uniform, amounting to 3.4 feet a mile (0.6‰).

3. Materials and Methods

3.1. Materials

In this work, the materials used concerned data and tools.

3.1.1. Data

All the data used in this paper have been extracted from the MSc. Thesis of Obayelu (2016):

- Land use/Land cover image map of Oluwa Forest Reserve in 2016.
- SRTM satellite data of January 2016, 30m spatial resolution, Source: <http://earthexplorer.usgs.gov/>
- GPS coordinates for *Terminalia species locations*

3.1.2. Tools

- ArcGIS 10.2 software for GIS analysis;
- GPS device for *Terminalia species locations* collection.

3.2. Methods

3.2.1. Random sampling method

The Random sampling method was used to carry out random selection of *Terminalia* species in the study area.

3.2.2. GIS Spatial analysis operations

3.2.2.1. Extraction of topographic factors

The SRTM satellite data was imported into ArcGIS 10.2 where the elevation, slope, aspect and hillshade was extracted using the spatial analyst tools.

3.2.2.2. Operation of Overlay using decision table

The GPS points of *Terminalia* species acquired on the study area was also imported into ArcGIS 10.2. Then it was overlay respectively on the slope, aspect and hillshade data extracted from the SRTM data to show their influence on the distribution of *Terminalia* species in the study area.

4. Results

4.1. Land use/Land cover image map of Oluwa forest reserve in 2016

The result of the classification of the land use and land cover classes in Oluwa forest reserve in 2016 is shown below (figure 2).

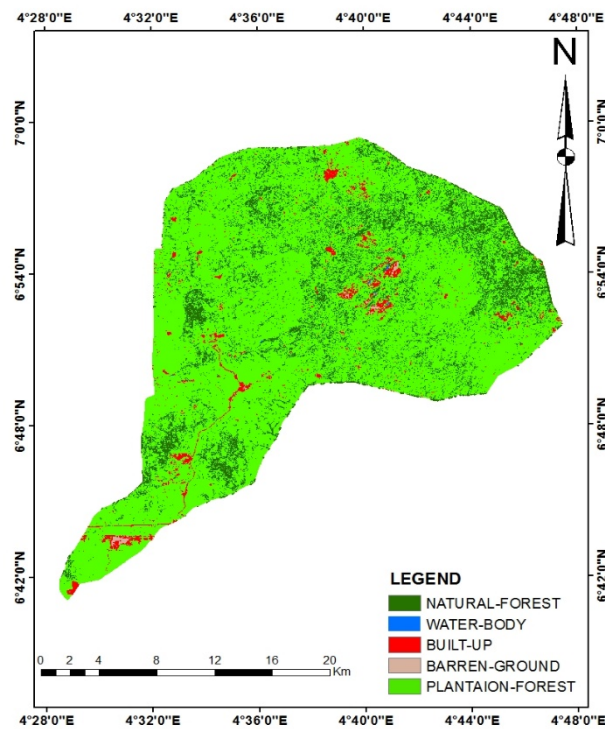


Figure 2. Land use/Land cover image map of Oluwa Forest Reserve in 2016

4.2. Species distribution and abundance in relation to the elevation

The species distribution and abundance in relation to the elevation of the study area varies from 36-95.78m to 95.78m and from 95.78m to 124.25m in which range there are more species of *Terminalia superba* and *Terminalia ivorensis* than in the range of 36 to 95.78m (figure 3).

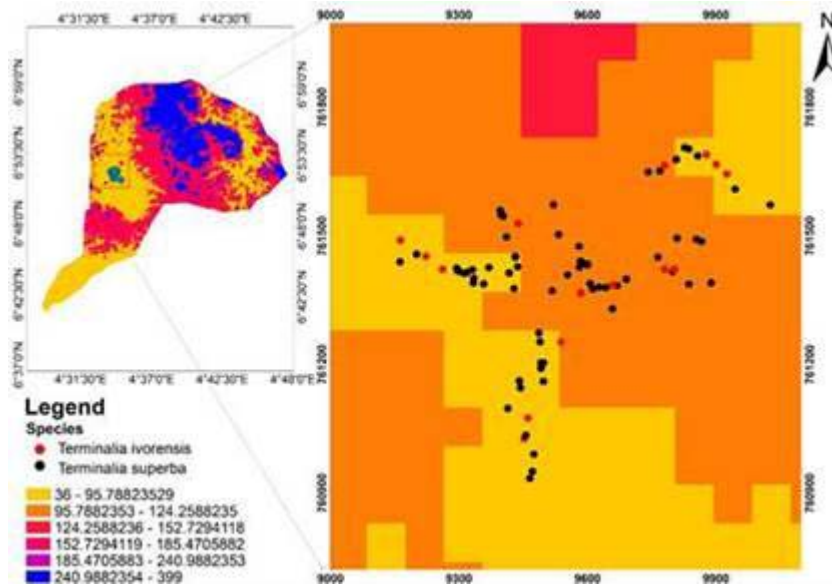


Figure 3. A zoom on *Terminalia* Species distribution in relation to Elevation in Oluwa Forest Reserve

4.3. Species distribution and abundance in relation to the slope

The species distribution and abundance in relation to the slope of the study area varies from 0 to 4.32 and 4.32 to 10.46 in which there are more species of *Terminalia superba* and *Terminalia ivorensis* in 0 to 4.32 than in the 4.32 to 10.46 in the study area as shown in figure 4.

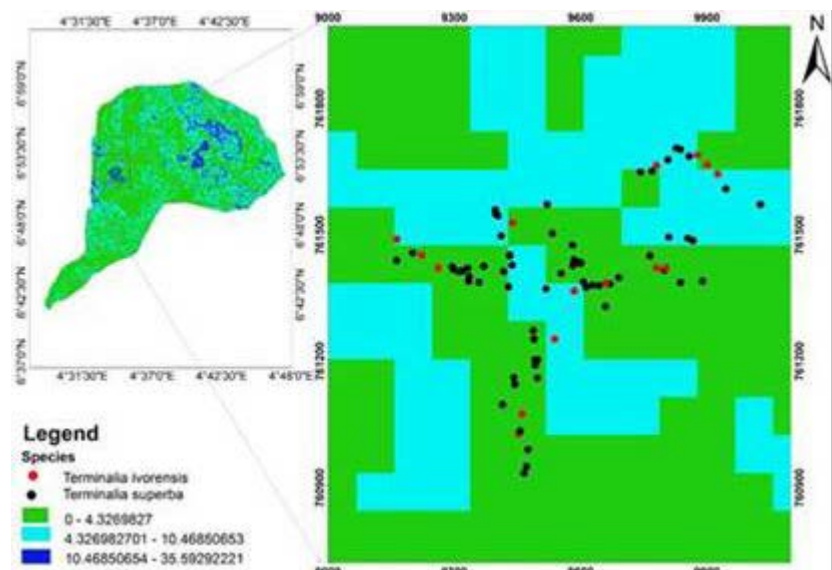


Figure 4. A zoom on *Terminalia* Species distribution in relation to slope in Oluwa Forest Reserve

4.4. Species distribution and abundance in relation to Aspect

The species distribution and abundance in relation to Aspect of the study area varies from high to low in which 337.5-360m is categorized as high and -1m is low in the study area. There are more species distribution and abundance in area that receive high sunlight than area with low sunlight in the study area as shown in figure 4.

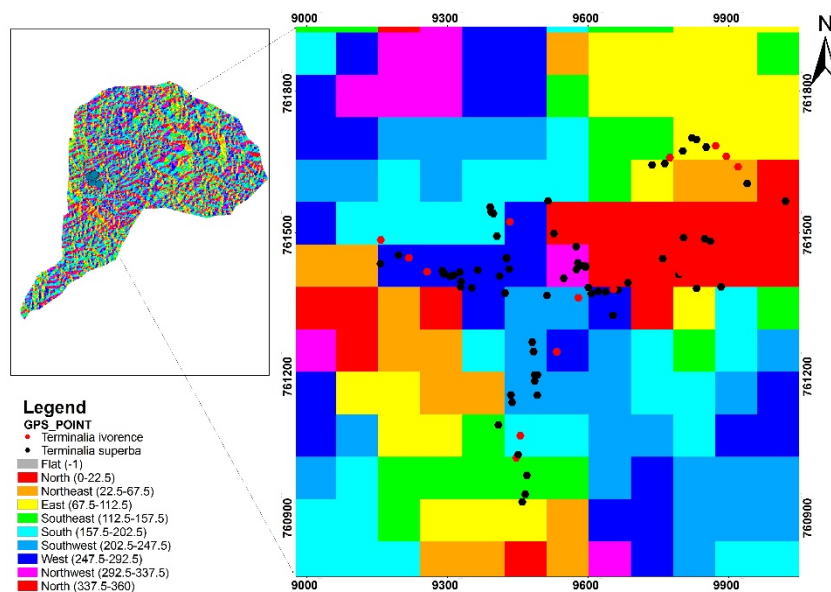


Figure 4. A zoom on Terminalia Species distribution in relation to Aspect in Oluwa Forest Reserve

4.5. Species distribution and abundance in relation to Hillshade

The species distribution and abundance in relation to Hillshade of the study area varies from high to low in which 247 is categorized as high and 46 is low in the study area. There are more species distribution and abundance in area with high hillshade than low hillshade in the study area as shown in figure 5.

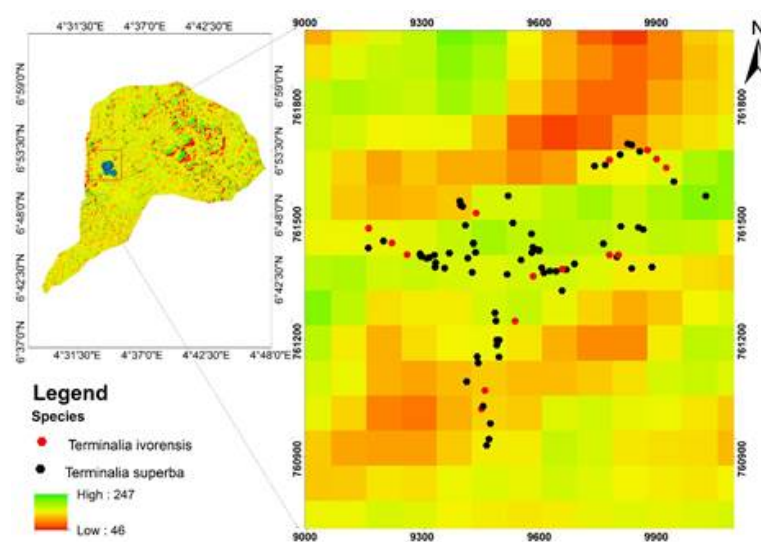


Figure 5. A zoom on Terminalia species distribution in relation to Hillshade in Oluwa Forest Reserve

4.6. Summary of the findings

Finally the summary of the findings of results reveal that factors including Elevation, Slope, Aspect and Hillshade have significant influence on the species richness, diversity and evenness in the study area. The results showed that elevation has a significant effect on diversity ($p = 0.305$) and richness ($p = 0.034$), ($p = 0.339$) so that area with lower elevation (0- 4.3269827 and 4.326982701 – 10.46850653 m range) had a higher value rather than upper elevation (10.46850654 – 35.59292221m above sea level) in part of plant diversity and richness. Area of Lower slope has a higher species distribution and richness, Aspect of the study area varies from 337.5-360m to -1m, area with 337.5-360m has higher species distributions while area of -1 has lower species distribution. Which implies that slope influence distribution and abundance in the study area. Hillshade of the study area varies from 247m to 46m, the portion of the forest with Hillshade of 247 is the area with higher species distribution while the area with Hillshade of 46m has lower species distribution. High to low in which 247 is categorized as high and 46 is low in the study area.

5. Discussion

The above results of the present study on *Terminalia* species distribution relative to Elevation, Slope, Aspect and Hillshade (mentioned in section 4.5. Summary of the findings), revealed that there are significant effect of topographic factors on species abundance and diversity pattern. They confirm the results of Basiri (2003) and Badano *et al*, (2005) in calcareous sites of Baritain, where species distribution was strongly influenced by slope and aspect. This condition occur because topography has effect on the solar energy obtained by the terrain which result in 10-20% deficit of moisture content in southern slope compared to the northern aspect (Perring, 1959). Across the study site, the North and south aspect had more abundance of *Terminalia* species diversity and richness, this is can be attributed to the nature of the environment which results in the lower tree cover density and thus increase the light level of the forest floor. Shmida and Wilson (1985) found out that the plant diversity is related to the edaphically heterogeneity (e.g the existence of rugged surfaces) in semi-arid environment in USA, so that the more rugged area would have more biodiversity than the other areas.

Our results also show that the species diversity is higher in low altitudes in the study area, in addition the lowest diversity has been shown in high altitudes. These confirmed the study carried out in Nepal by Grytnes and Vetaas (2002) who stated that the highest plant diversity exists in the middle altitudes and it reduces as the altitude increases which confirm the result obtain in the present study. In the study carried out by Siahkal forests of Northern Iran, Fellaoui and Marvie (2004) shows that the minimum value of diversity and richness can be found in the highest altitude. In this study, slope, elevation, aspect and hillshade had significant influence on species abundance and diversity.

6. Conclusion

During the forest inventory of this study only two species of *Terminalia* was identified which are *Terminalia superba* and *Terminalia ivorensis*. The analysis of the above results showing that topographic factors including Elevation, Slope, Aspect and Hillshade have significant influence on the species richness, diversity and evenness in the study area. This kind of situation observed by others researchers all over the World led Ecologists to propose solution through numerous mechanisms of species coexistence, including the niche theory, neutral theory, and negative density dependence mechanisms.

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