IRESPUB Journal of Environmental & Material Sciences
ISSN: 2770-4084
Volume: 2 | Issue: 5 | MAY - JUN 2023 | Available Online: www.irespub.com

Spatial Diversity Mapping of Plant Species in Karlahi Forest Reserve, Fufore Local Government Area of Adamawa State

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ABSTRACT
The analysis of the spatial species diversity in Karlahi Forest Reserve of Fufore Local Government of Adamawa State, Nigeria was carried out and it was aimed at analyzing the distribution of tree species within the forest reserve which is vital to the understanding of changes that occurred within the forest. This research adopted three methodological approaches that are, the use of Geographic Information System (GIS) and field investigation to determine the species diversity. The results of the species diversity show that zone 3 has the highest species richness with Bauhinia thonningii and Anogeissus Leiocarpus also known as "Kalgoo" and "Mark" in Hausa language respectively as dominant species and species endemism, zone 4 has the highest species red list followed by zone 3 and 2. The common species that make the red list are Pterocarpus Erinaceus, ziziphus spina-christi, Balanites Aegyptiaca, Vitellaria paradoxa, Anogeissus Leiocarpus, banhinia thonningii, Parkia Biglobosa, Detarium microcarpum. It is recommended that Land Cover information and regular species diversity audit should be incorporated into the conservation practices and Nation and state policies on Forest reserves and parks should be adhered to strictly.

KEYWORDS
Species Richness; GIS; Endemism; quadrant

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1. INTRODUCTION

Plant species richness is a key component of global biodiversity, playing a critical role in supporting a wide range of ecosystem functions and services. However, recent research has shown that plant species richness is under threat from a variety of human activities, including land use change, habitat fragmentation, and climate change. Climate change, in particular, is expected to have significant impacts on plant communities around the world, with potential consequences for the diversity and abundance of plant species, as well as for the ecosystems and human societies that depend on them. This paper seeks to explore the effects of climate change on plant species richness, drawing on a range of empirical studies and theoretical models to assess the ways in which changing environmental conditions are likely to impact plant communities in different regions and ecosystems. By examining the complex relationships between climate, plant species richness, and ecosystem function, this research aims to contribute to our understanding of the challenges and opportunities associated with managing and conserving plant biodiversity in the face of global environmental change.

The issue of species diversity is a critical problem facing our planet today. As the world's population grows and human activities continue to alter the natural environment, many species are threatened with extinction. The loss of biodiversity can have significant ecological, economic, and social consequences, including the disruption of ecosystems, the reduction of natural resources, and the loss of cultural and aesthetic values. [1]. One of the key challenges associated with species diversity is the need to identify and prioritize conservation efforts. With limited resources and an ever-increasing number of threatened species, conservationists must make difficult decisions about which species to focus on and how to allocate resources effectively. This requires a deep understanding of the ecological, genetic, and evolutionary factors that contribute to species diversity, as well as the economic and social factors that drive human behaviour and decision-making. Another important aspect of the problem is the need to understand the consequences of species loss for ecosystem function and resilience. As species disappear, ecological communities may become less stable and less able to provide critical ecosystem services such as nutrient cycling, pollination, and pest control.

This can have cascading effects on other species and on human well-being, including impacts on food security, human health, and the economy.

The problem of species diversity is complex and multifaceted which is requiring interdisciplinary approaches that integrate ecological, economic, social, and cultural perspectives. Addressing this problem will require innovative research, effective communication, and collaboration across diverse sectors and stakeholders. [2, 3]

This research looked at the spatial distribution of plant species within Karlahi Forest Reserve in Fufore Local Government of Adamawa State Nigeria and factors affecting the spatial distribution of such species.

1.1 Location and Extent

Karlahi Forest reserve is situated in Fufore Local Government Area of Adamawa State. It is located between latitudes 8049′30′′N and 9000′N, of the equator and longitudes 12036′0′′E and 12045′0′′E of the prime meridian. Its land area is estimated at about of 122.5 sq. Km [4]. Karlahi Forest Reserve is bounded by the Toja Stream to the North and Beti Stream to the South-to-South Eastern part. Relief of the study area lies between the range of 197m and 346m above sea level and characterized by a gentle slope. The area is predominantly constituted by arable and range lands. The area is bounded to the North by a plain with elevations ranging from 197m and 242m above sea level, and to the south by the Varre hill. The dynamics of land use are conditioned by relief areas with high slope, this factor increase the fragility of the system and decrease the possibility of anthropic use, which makes area with low relief (Slope) vulnerable to many agents of deforestation [5].

Climate of the study area is characterized by humid tropical climate; marked by distinct wet and dry seasons in which the wet season lasts for Six to seven months with annual precipitation values ranging from 656.70mm to 1260.10mm [6]. The months of July and August has the highest rainfall while the driest months are January, February and December [6]. The dry season which predominantly occurs from November to May is characterized by high mean evaporation values, mostly from the months of January to March/April with mean monthly values ranging from 115.40mm to 255.76mm and annual values ranging from 1585mm to 2922.87mm [6].

2. METHODOLOGY

This section describes the procedural framework within which this research has been conducted, and how the solution to the research problem was practically approached during the research process.

2.1 Types and Sources of Data

2.1.1 Data Types

For the purpose of this study the following data were used:
Shuttle Rader Topography Mission (SRTM) Digital Elevation Model (DTM) data of 30m resolution obtained from the United States Geologic Survey website (earthexplorer.usgs.gov) was used for the sampling design which involve the clustering/Stratifying of the Sample areas.

Number of Species at each stratum was used to generate species richness at each stratum using the Menhinick's index of species richness, this index was obtained by dividing number of species found in each stratum of the study area by square root of the number of individuals in the stratum as expressed in equation 1.

$$D=s/\sqrt{N}$$

Where D = Species Richness
S = Number of species
N = number of individual species

Data used in this study were obtained from primary and secondary sources. Specifically, the data from primary sources which include field measurement. The secondary data include information obtained from books, journals, unpublished materials

2.2 Sampling Procedure

Two methods of sampling were employed for this research. That is, multistage and Systematic Sampling approaches. Multistage sampling method was used to draw the population element of the study area and this sampling approach was conducted in various level of sampling: Strata, Cluster and Random sampling.

Strata: the relief of the forest reserve area was used as the population element which were divided into mutually exclusive non-overlapping clusters of sample units called strata, the division was on natural breaks using Jenks method of classification (this considered the minimum and maximum relief value, mean and as well as the standard deviation of the value) in ArcGIS 10.5 on the relief of the area ranging from 197-236m (zone 1), 236-267m (zone 2), 267-297m (zone 3) and 297-346m (zone 4) as shown in Figure 1.

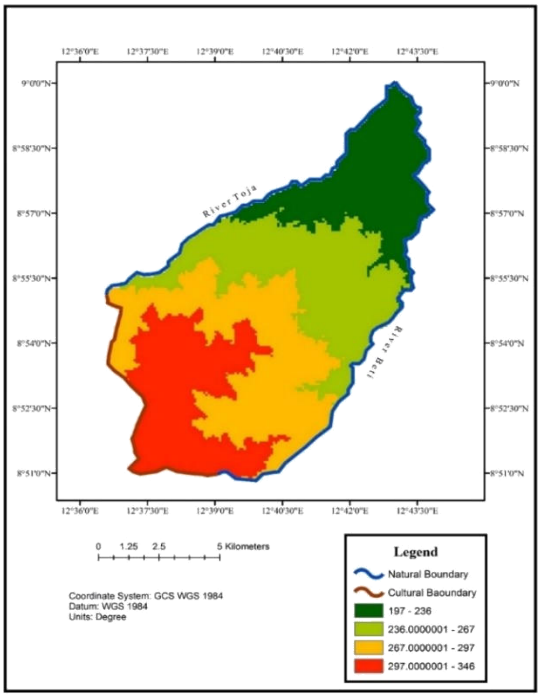

FIGURE 1: Relief Stratification in Karlahi Forest Reserve.
Source: USGS

Cluster: The individual Stratum in Figure 1 were further divided into clusters of squares with dimensions of 1.5x1.5 km grid such that each square grid covered an area of 2.25 km2 as shown in Figure 2.

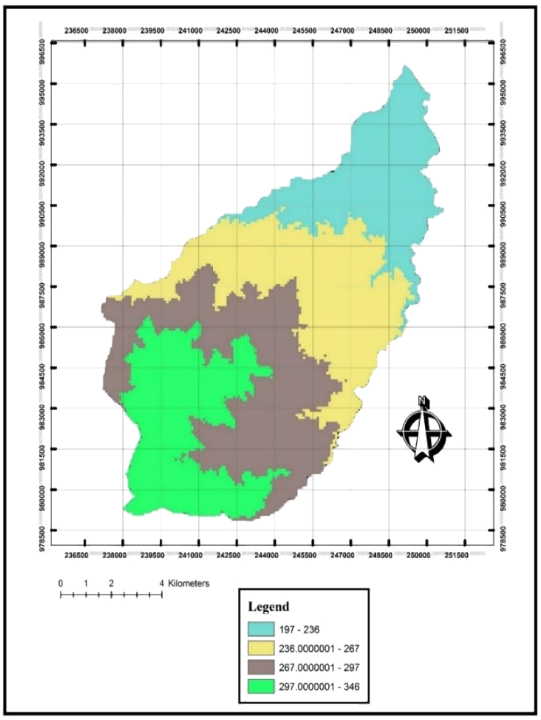

FIGURE 2: Cluster Grid of 1.5*1.5 Km in Karlahi Forest Reserve.
Source: USGS

Thirty (30) percent of the population size (number of 2.25km² grid that cover the individual strata) was considered as sample size and sample areas were calculated from the number of sub-clusters (2.25Km²) that cover the individual Strata as shown in table 3.1

TABLE 1: Sample Percentage in Each Stratum.

Stratum (m)	Population Size	Number of Sample Units (30%)
197-236	23	7
236-267	33	10
267-297	35	11
297-346	21	6

For example, stratum 197-236 explains table 3.1, 23 number of 2.25Km² cover the stratum and 30% of 23 using sample percentage is 7.2. Therefore, seven (7) out of the 23 clusters of 2.25Km² were sampled and this process was applied for the remaining strata as result showed in Table 1.

Random Sampling: This technique was used to draw the first vegetation species sample area (Cluster) within a stratum. This was done by assigning a value to every potential sample unit (cluster) in each stratum with no units excluded as in stratum 197-236 (m) (figure 3.3). The 2.25km² grid were assigned numbers then sample area were selected through lucky-dip assigned to the clusters as shown in figure 3.3, same technique was employed for all the strata and the result presented in Table 2 and Figure 3.

TABLE 2: First Random Sample Cluster in Each Strata.

Stratum	First Random Number
197-236	6
236-267	3
267-297	2
297-346	1

2.2.2 Systematic Sampling Approach

From the first random numbers of each stratum in Table 2, a systematic sampling approach was used to determine the subsequent number of Species sampling clusters using the systematic sampling formula:

$$k = N/n$$

Where *K = Sampling Interval*
N = Population Size
n = Sample Size

Sampling interval (K) from the first random cluster in each stratum was calculated and result shown in Table 3.

TABLE 3: Sampling Interval.

Strata	N	n	K
197-236	23	7	3
236-267	33	10	3
267-297	34	11	3
297-346	21	6	3

The sample clusters of each stratum were obtained by the first random number obtain from the simple random sample as shown in Table 2, then taking the systematic interval (K) in consideration as shown in Table 3. For instance, taking strata 197-236 for example, the first random number is 6 (Table 2) and the systematic interval (K) is 3 (Table 3). Therefore, 6+3=9, 9+3=12…. 7_{th} sample cluster which is the 30 percent of the total cluster population obtained for the stratum as shown in Table 3.4. However, the total number of population size in stratum 197-236 is 23 and the 6^{th} geometric number is 21. Therefore, to determine the 7^{th} sample pixel 21+3=24, although the population size in this stratum is 23, therefore the next geometric number must be 1 as the number of cluster (population size) ends at 23. This same method was done for the subsequent strata and clear example of such sample location area clusters were shown in Table 4 and on Figure 4.

TABLE 4: Systematic Random Number of clusters.

Strata	Sample Pixel
197-236	6, 9, 12, 15, 18, 21, 1
236-267	3, 6, 9, 12, 15,18, 21, 24, 27, 30
267-297	2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 32,
297-346	1, 4, 7, 10, 13, 16

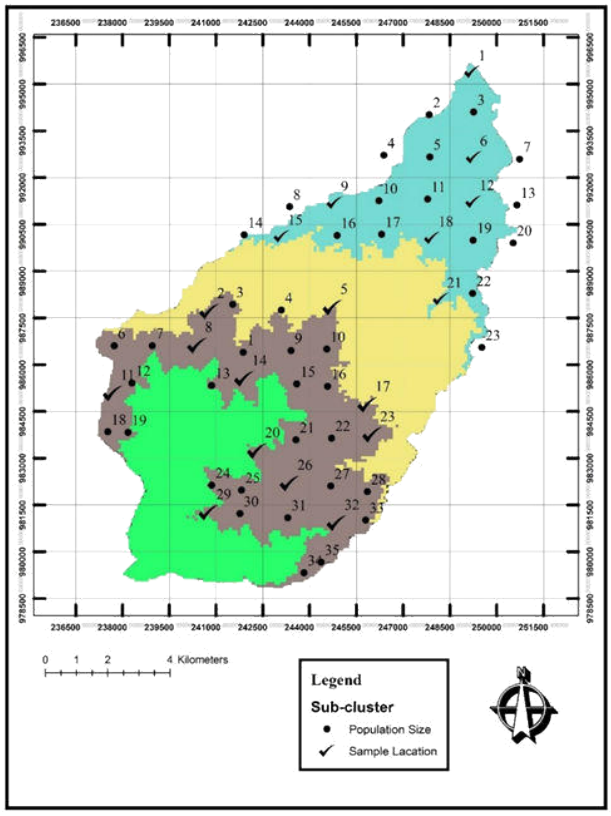

FIGURE 3: Species Sampling Clusters in Karlahi Forest Reserve.

Figure 3 shows the final sample locations in the study area. That is, all the location clusters (pixels) with symbol (√) were the selected sample from which data were collected.

2.3 Method of Data Collection

(1) Establishment of quadrants: A sample quadrant of 900m^2 were taken within each cluster of 1.5x1.5Km^2 randomly, data on sample units area coordinate and elevation were collected using the Global Position System (GPS) from this 900m^2 quadrants, vegetation species count were carried out to determine the total number of trees within that sample area.

(2) Measurement of Species at Karlahi Forest Reserve: Counting and observation of individual tree and shrubs species were sampled from the target population for data collection where data on number of species for each cluster was collected and generalized for the stratum and from these data a species richness, species endemism and species red list were calculated for each stratum.

(3) Species richness for each stratum was calculated using the number of species sampled from the 900m^2 quadrants in each stratum divided by the square root of the number of species found within the study area and were generalize for the whole stratum which is number of species per specified number of individuals.

3. RESULT AND DISCUSSION

3.1 Specie richness

The distribution of different tree and shrubs species over the landscape of Karlahi Forest Reserve is what constitutes its diversity in respect to its species richness. Out of the total of 4,862 trees and shrub stands that were counted within the 34 randomly sampled plots in the four (4) zones of the forest reserve, 44 different species of tree and shrubs were counted. This number of species in Karlahi Forest Reserve correlates to the findings of Omijeh and Tella [8] in the neighboring Bagale Forest Reserve located in the same Guinea savannah vegetation area where nearly all the species found in Bagale Forest Reserve were also found in the Karlahi

Forest Reserve. Most of the species found in the area are mostly Tropical African plant species. But the dominant species in Karlahi forest are *Bauhinia thonningii and Anogeissus Leiocarpus* also known as "Kalgoo" and "Marke" in Hausa language respectively (Appendix 1). This finding relative abundant species found in Karlahi Forest Reserve do differs from that of Omijeh and Tella [8] that in Bagale Forest Reserve, *Vitellaria paradoxa* and *Lannea Kersting* were the dominant species.

Among the four classified zones of the forest reserve, zone 3 (Z3) has the highest number of species (Appendix 1) as well as the highest richness index as shown in Table 5 and Figure 4

TABLE 5: Zonal Distribution of Species Richness.

	Number of species			
Zones	Z1	Z2	Z3	Z4
Number of Species	28	40	43	39
Menhinick's Species Richness Index	4.22	6.03	6.48	5.88

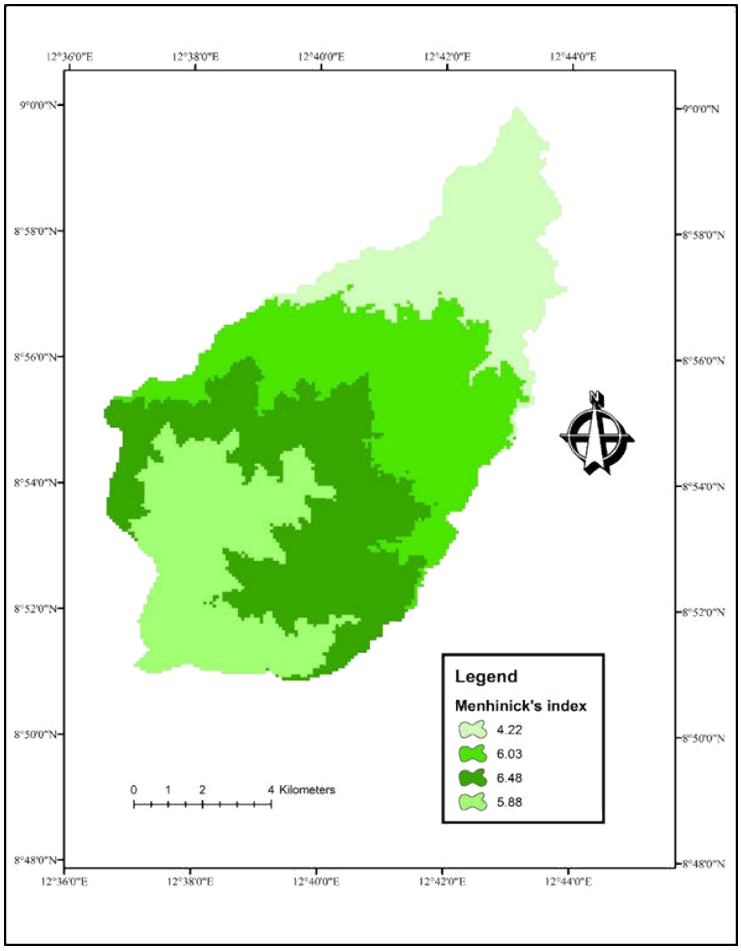

FIGURE 4: Spatial distribution of Manhinik's Species Richness.
Source: Researcher 2021.

Figure 4 shows the spatial pattern of menhinicks species richness index within Karlahi Forest Reserve and the variation in the species distribution along the zones were attributed to the relief of the area. Upland area has much vegetation cover than the lowland area which is in line with the finding of Silva, Metzger and Bernacci [9] that vegetation on the lower area of Forest is degraded as people always clear them to give way for farming activities. The issue of insecurity within Karlahi Forest Reserve makes some zones especially the higher altitude unsuitable for logging and other anthropogenic activities thereby making the area to have higher species number which translate to species richness.

Most of the species found in the Karlahi Forest Reserve were under the classification of Tropical African Species which are predominately found in West African countries and Tropical African countries. A total of 23 plant species were considered endemism species within the four zones in Karlahi Forest Reserve as shown in Table 6.

TABLE 6: Zonal Distribution of Weighted Species Endemism.

	Z1	Z2	Z3	Z4
Endemism	13	19	23	20
Weighted Endemism index	0.62	0.90	1.10	0.95

The nature of this variation among the four zones in Karlahi Forest Reserve might be as a result of the nature of the terrain which is nearly flat land with Gleyic Combisol and Eutric Regosol soil type which are characterized by high content of nutrients washed down from the hill slopes and the soils are naturally fertile enough to support significant agricultural productivity and in line with this people settle within the zone and this result to cutting down of trees to give way for agricultural activities and this result to degradation of the forest reserve and making such areas with few species of vegetation [10].

The threat to tree species in Karlahi Forest Reserve is destruction of the vegetal cover due to logging activities or forest conversion to other land uses. Information extracted from KII revealed that logging activities within the forest reserve have impacted on the species of trees and shrubs within the Karlahi Forest Reserve which partially or completely remove the species from the area as discovered, among the species that were found to be exploited in high quantity and nearing extinction were the *Pterocarpus Erinaceus, ziziphus spina-christi, Balanites Aegyptiaca, Vitellaria paradoxa, Anogeissus Leiocarpus, bauhinia thonningii, Parkia Biglobosa, Detarium microcarpum*. The quantity of woodland and shrubs in each of the zones which are exploited the most stand a chance of being degraded within the Karlahi Forest Reserve and some of these species are found at the higher altitude. That is, zone four of the study area with thin soils, makes it to have the highest number of endangered species. This number of species which were been logged for timber, animal food, charcoal extraction as well as for agricultural activities are reducing drastically and thereby depleting the Karlahi Forest Reserve. This finding has become the major trends in most northern Nigerian [11].

CONCLUSION

Result of the spatial species distribution shows that zone 3 has the highest species richness and species endemism and this is as a result of both factors depends on the number of species found in the individual zones but species red list is number of species of trees and shrubs which are most exploited within the individual zone and zone 4 has the highest as most logging activities is taking place within the zone as higher number of the species endanger are in zone 4 with 1.12 index followed by zone 3 and 2 with 0.94 respectively. The common species that makes the red list are: *Pterocarpus Erinaceus, ziziphus spina-christi, Balanites Aegyptiaca, Vitellaria paradoxa, Anogeissus Leiocarpus, banhinia thonningii, Parkia Biglobosa, Detarium microcarpum.*

RECOMMENDATION

Adamawa State Ministry of Environment and Natural Resource Development has been established to effectively prevent flora and fauna destruction. The study of the Karlahi Forest Reserve species diversity reveal that a greater part of the forest reserve was altered. Protecting the total area of the forest reserve area from the device anthropogenic activities within the forest reserve can attempt to remedy the effect of the anthropogenic activities may serve a remedy in the protection of the endangered species as well as to protect the species of plants within the forest.

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Appendix 1
Species Diversity

	Species	**Local Names**
1	Crossopteryx Febrifuga	Kashin akuya
2	Faidherbia albida	Gawo
3	Commiplora Africana	Dashi
4	Senna singueana	**Runhu**
5	Pericopsis laxifilora	
6	Steculia setigera	Kukuki
7	Lannea acida	Faruhii
8	Sarcocephalus Esculentus	bambami
9	uvaria chamae	Kas kaifi
10	Isoberlinia Doka	Takalmin Zoomoo
11	Pterocarpus Erinaceus	Madobiya
12	Kigelia Africana	noonon Giwa
13	Ximenia Americana	Tsada
14	Adanonia digitata	Kuka
15	Bombax costatum	Gurjiya
16	Maerua Angolensis	Gazare
17	Oncoba spinosa	Kookon Biri
18	Tamarindus indica	tsamyia
19	Entada Africana	**Tawatsa**
20	Sclerocarya birrea	danya
21	Hymenocardia Acida	**Janyaro**
22	Terminalia loxiflora	**Baushe**
23	Burkea Africana	Kiriya Dutse
24	Detarium microcarpum	Taura
25	Acacia Senegal	Dakwara
26	Grewia Mollis	Dargaza
27	Piliostigma Thonningii	**Kalgoo**
28	Afzelia Africana	Kawo
29	Ceiba Pentandra	Rimi
30	Combretum molk	Ɗinyar gata
31	Ficus	
32	Lannea kerstingii	Faarun Dooyaa
33	ziziphus spina-christi	**Kurna**
34	Daniella oliverii	Maje
35	Terminalia glaucescens	**kandaré**
36	Parkia Biglobosa	Daurawa
37	Vitex doniana	**Dinya**
38	Balanites Aegyptiaca	Aduwa
39	Prosopis Africana	Kirya ta mataa
40	Boswellia dalzielii	Harrabi
41	Vitellaria paradoxa	**Kaɗanya**
42	Annona senegalensis	Gwandan daji
43	Anogeissus Leiocarpus	Marke
44	banhinia thonningii	**Kalgoo**