ECOLOGICAL LANDSCAPE ANALYSIS OF SAVANNA WOODLAND AREA IN NIGER STATE, NIGERIA

By

Jibrin Abdullahi

Department of Geography and Environmental Management,
Ahmadu Bello University, Zaria, Nigeria
Correspondence: abdullahi717@hotmail.com

ABSTRACT

There is widespread concern that landscape ecology of savannah woodlands are poorly understood particularly in sub-Saharan Africa. Climate change mitigation concerns and sustainable conservation necessitates a sound understanding of savannah woodlands spatial heterogeneity. The aim of this study is to examine the appearance and patterns of savannah woodland ecological landscape in Niger State. A forest reserve and adjoining parkland area were used as study sites. Field survey method involving inventory and biometric/morphometric measurement techniques were employed for data collection. The structural variables (Tree Height, Girth, Diameter at Breast Height- dbh, Basal Area, Crown cover, Shrub cover, Grass cover) and composition variables (Tree Density, Species per plot, Species richness and Diversity) were analysed. Findings revealed that the plant community structure exhibit variability in pattern among virtually all the parameters. The results also portray that the forest reserve plant community structure parameters exhibited downward skewness and more dispersion in mid values; while the parkland exhibits almost symmetric data set with equal dispersion. Further, all measures of plant community composition in the study area suggest a heterogeneous spatial distribution of species both in the forest reserve and parkland. The observed heterogeneity was partly due to deforestation and forest degradation which could enhance atmospheric carbon concentration. The study thus recommends adoption of carbon offset projects in the study area for effective conservation of the ecological landscape and enhancement of carbon sink.

Key words: Ecology, Landscape, Heterogeneity, Parkland, Savanna woodland.

INTRODUCTION

Landscape ecology of savannah woodlands are poorly understood particularly in sub-Saharan Africa. The ecosystems making up a landscape generally form a mosaic of visually distinctive patches that vary in size, shape, configuration and connectedness; which determine spatial patterns over an expanse of land (Jibrin, 2014). Landscape ecology is concerned with the study of structure, function, and change in a heterogeneous land area which contains interacting ecosystems (Forman and Godron, 1986). Landscape structure includes the size, shape, composition, number, and position of different ecosystems within a landscape (Forman, 1987).

Ecological landscape assessments requires the quantification of landscape structure; because natural and human activities have often altered landscape structure and processes.

Ecosystems render diverse services to humanity from their composition and structure but the preservation of these ecosystem services needs a clear understanding of their complexity; hence, there is growing interest in ecological landscape assessment. Environmental heterogeneity with its three major components (the variability of environment or range of environmental conditions, habitat spatial configuration, and variation over time) underpins the principles of Landscape ecology. The environmental heterogeneity hypothesis states that species richness increases with the number of ecological niches; that is, species coexistence is facilitated in more heterogeneous environment because different taxa can capitalize on different environmental conditions (Ricklefs, 1977; Bormann 1987).

Every ecosystem is a complex organization of carefully mixed life forms; which makes ecosystems exhibit common attribute of diversity worldwide and produce various functionalities according to ecologic regions. In this current context of climatic changes, these ecosystems undergo notable modifications, amplified by domestic uses that it is subjected to. Preservation of these ecosystem functions and services thus needs a clear understanding of their complexity and spatial configuration.

While guinea savannah plant formation in Niger state is characterised by local variation in community composition, diversity, and spatial structure of these forests (Jibrin, 2009; Jibrin and Jaiyeoba, 2013), their landscape ecology remain poorly understood. The aim of the study is to examine the appearance and patterns of savannah woodland ecological landscape in Niger State, Nigeria. The objectives of the study were to identify the structure and composition of woody plant communities; assess the configuration of plant communities; and examine the ecological land scape of the savannah woodland in Niger State, Nigeria.

THE STUDY AREA

The study was carried out in Kpashimi Forest Reserve and adjoining Parkland area; situated in Lapai Local Government Area of Niger State, Nigeria. The study area is located between latitude 8^o 39′ to 8^o 50′ North and longitude 6^o 34′ to 6^o 46′ East (See Figure. 1). The forest reserve is approximately 213.101 square kilometres while the delineated parkland situated adjacent to the forest reserve is 58.361 square kilometres. The two areas are separated by a main road; as shown on Figure 1. The study area is characterized by alternating wet and dry season coded as ‘Aw’ by Koppen’s classification. The long term mean annual rainfall is 1,400 mm with mean annual air temperature of 28^oC (Ojo, 1977). The study area lies within the southern Guinea savannah zone, classified as woodland savannah vegetation with the understory dominated by annual grasses (Keay, 1953).

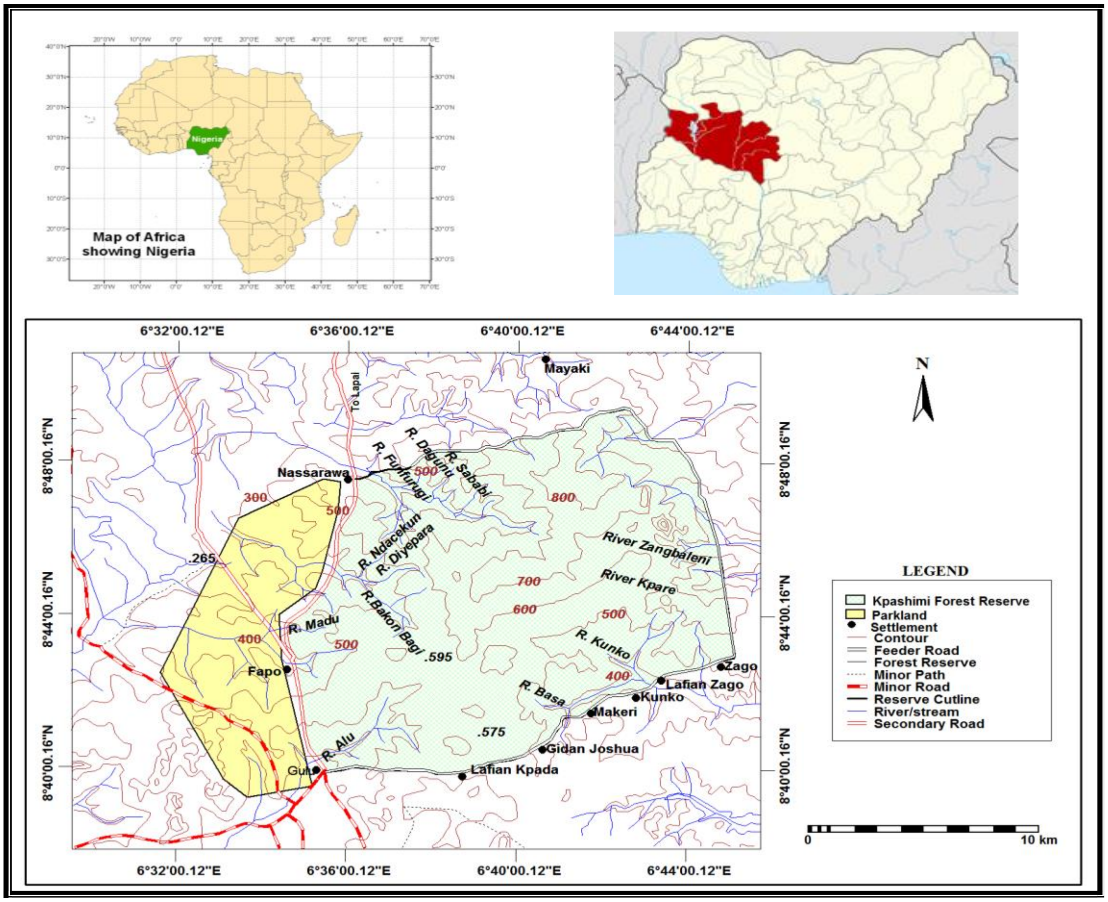

Figure 1 Geographical location of study area

Source: Adapted and modified from Nigeria 1:100,000 GULU SHEET 206, 1967

MATERIALS AND METHODS

A forest reserve and adjoining parkland area were used as study sites. Reconnaissance survey was conducted at the preparatory stage of the study, and subsequently followed by pilot survey which was followed by detailed field survey. Philip (1994) method for calculation of sample size was employed in this study. The Formula yielded 45 sampling units of 500 m^2 quadrats.

$$n = \frac{CV^2\, t^2}{E^2} \quad \text{(Philip, 1994)}$$

Where:

CV = is the coefficient of variation of tree basal area at breast height

t = is the t value for the 95% confidence interval.

E = is the allowable sample error of estimation.

Field survey method involving inventory and biometric/morphometric measurement techniques were employed for data collection in accordance with field techniques presented in Table 1.

Table 1: Measurement Techniques of Plant Community Parameters

S. No	Parameter	Method	Source
1.	Tree height	Clinometers	Gareth, (1991)
2.	Tree Diameter at Breast Height	Girth conversion	Hairiah et al, (2010)
3.	Tree Basal Area	Formula	Hairiah et al., (2010)
4.	Tree density	Enumeration	Eyre et al., (2006)
5.	Tree Species Richness	Margalef Index	Margalef, (1958)
6.	Tree species diversity	The Shannon index (H′)	Shannon and Weiner, (1963)
7.	Tree Species Dominance	Species Importance Value (SIV)	Cottam and Curtis (1956)
8.	Tree Crown cover	Line transect	Eyre et al., (2006)
9.	Percentage Shrub cover	Line transect	Eyre et al., (2006)
10.	Percentage Grass cover	Line transect	Eyre et al., (2006)

RESULTS AND DISCUSSION

The morphometric inventory operation yielded data on the structural physiognomy of plant communities in the study area; as presented in Table 2 showing that all measured physiognomic attributes of plant communities were higher in the forest reserve with mean tree height (16.7 metres), tree girth (76.9cm), tree dbh (24.5cm) and basal area (5.6 m^2 ha^{-1}); whilst lowest values were observed in the parkland with mean tree height (12.3 metres), tree girth (60.5cm), tree dbh (19.3cm) and basal area (3.5 m^2 ha^{-1}). Further, the Forest reserve is characterized by about 50 % crown cover, a scarce discontinuous shrub (20.8 %) and grass layer (25.2 %).

The open woodland had an upper stratum of deciduous trees of small to medium size, with their crowns more or less touching above a sparse woody stratum. The parkland was characterised by isolated scanty crown cover of about 14%, but ground layer consists of shrubs (48 %) and grasses and herbs of high density (70 %). This could be attributed to incidence of deforestation and forest degradation which had resulted in elimination of more tree species and dominance of annual grass and herb species in the parkland.

Table 2: Descriptive Statistics on Structure of Plant Communities

Parameter	Physiographic Unit	N	Minimum	Maximum	Mean	Standard Deviation
Tree Height (metre)	Forest Reserve	1816	4.5	36.5	16.69	5.64
	Parkland	345	4.3	24.2	12.30	3.81
Tree Girth GBH (cm)	Forest Reserve	1816	5	187	76.86	33.17
	Parkland	345	15	146	60.53	26.96
Tree Diameter DBH (cm)	Forest Reserve	1816	4.59	59.55	24.48	10.56
	Parkland	345	4.78	46.5	19.28	8.59
Tree basal area (m^2 ha^{-1})	Forest Reserve	1816	0.02	27.86	5.58	4.30
	Parkland	345	0.18	16.98	3.50	2.97
Tree Crown cover (%)	Forest Reserve	30	34	69	50.23	9.68
	Parkland	15	12	16	14.13	1.19
Shrub cover (%)	Forest Reserve	30	6	47	20.77	8.84
	Parkland	15	34	57	48.07	6.08
Grass cover (%)	Forest Reserve	30	8	40	25.20	9.08
	Parkland	15	61	85	70.33	7.24

Source: Author’s field work, 2016

The analysis of structural attributes reveal that tree height in the forest reserve (Figure 2a) indicates upward skewness (larger dispersion of taller trees), clustering of medium and short trees with isolated outlier; whereas the parkland exhibited moderate dispersion of tall and short trees with isolated outliers. Girth and dbh size distribution in the forest reserve (Figures 2b and 2c) shows symmetric distribution with clustering of medium girth and dbh sizes while parkland indicates more spread in the fourth quartile of girth and dbh sizes with some isolated outliers. With regards to the distribution of basal area as illustrated in Figure 2d, the forest reserve was characterised by upward positive skewness (larger dispersion of bigger basal area) with small dispersion in the middle and lower basal area sizes; while parkland exhibits clustering of lower basal area, large spread in the fourth quartile with several outliers. The distribution pattern of plant community structural characteristics suggests much variability as a result of the interplay between the ecological amplitude of the species, environmental heterogeneity and anthropogenic interference. This corroborates the views of (Bormann, 1987; Frost, 1996) that the composition and structure of any given vegetation community reflects the interaction between its component members and their environment through time.

All measures of structural characteristics were more variable in the forest reserve with higher values of standard deviation and least values in the parkland. This observed heterogeneous pattern of the ecological landscape in savannah woodland is often attributed to environmental heterogeneity (Menaut *et al.*, 1995). The relatively lower structural attributes in the parkland may be an indicator of woodland deforestation, degradation, fragmentation and local species extinction (Jibrin, 2009; 2013); resulting from unsustainable harvesting of firewood for charcoal production, uncontrolled grazing and bush burning.

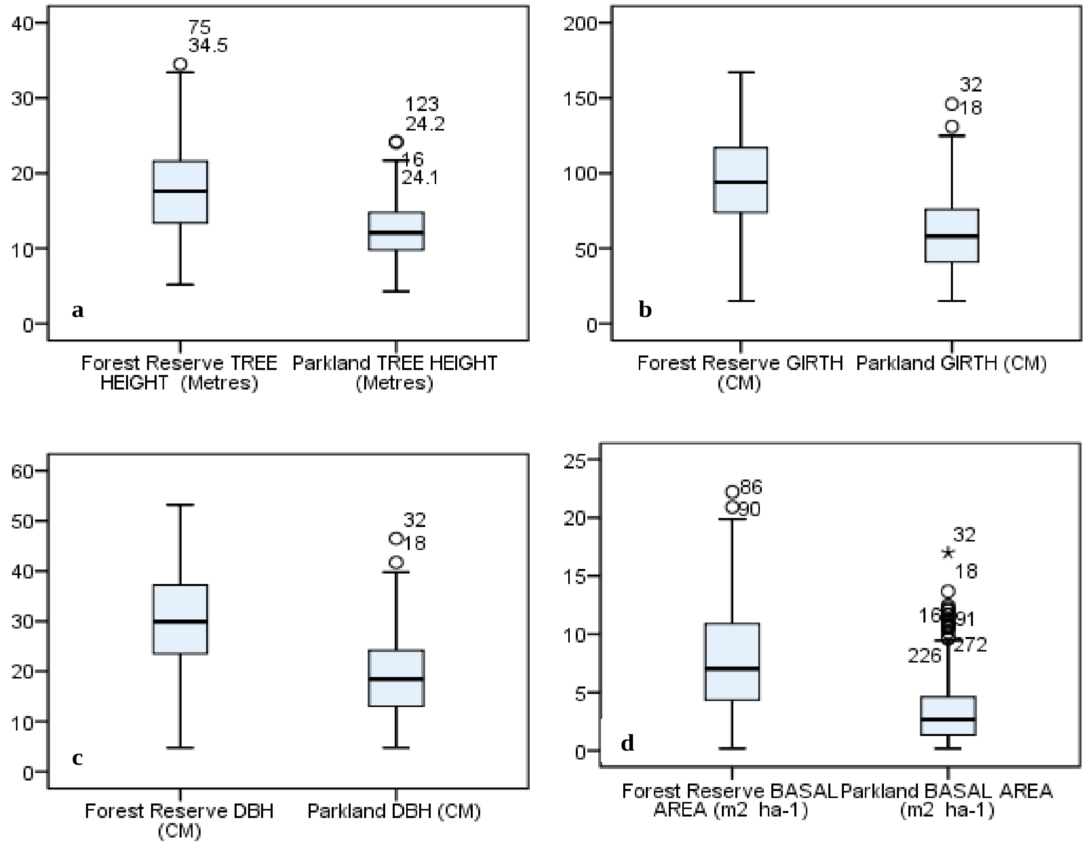

Figure 2: Spread of Data on Plant Structural Attributes
Source: Author's field work, 2016

The pattern of data distribution on plant cover occurrence in the forest reserve shows that in the forest reserve, crown cover shows large dispersion of high percentage crown cover with upward skewness, whereas the parkland exhibits clustered low percentage crown cover (see Figure 3a).

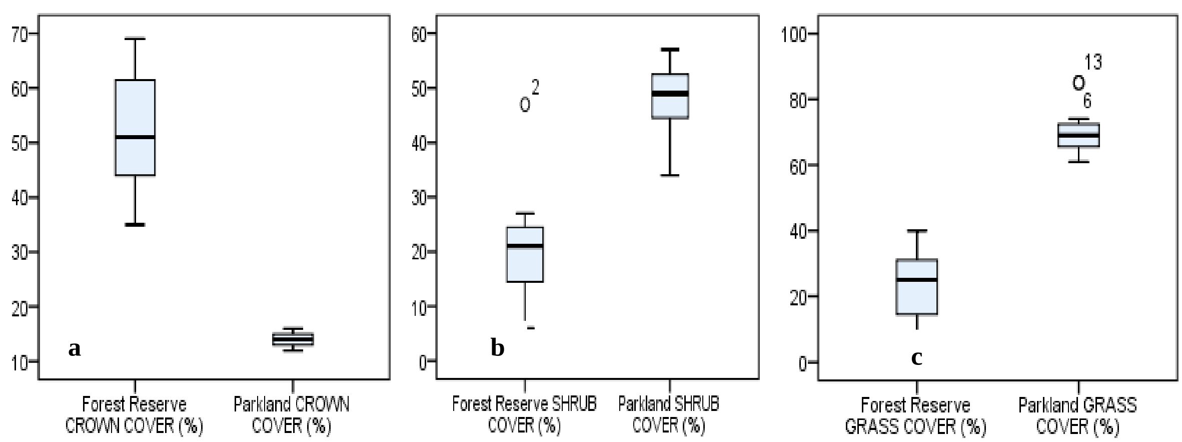

Figure 3: Spread of Data on Plant Cover
Source: Author's field work, 2016

Figures 3b and 3c illustrates shrub cover and grass cover in the forest reserve being characterised by downward skewness with spread of low percentage shrub cover and grass cover. On the other hand, the parkland shows moderate dispersion of high percentage shrub cover and middle clustered high percentage grass cover with some outliers. The implication of these patterns of crown cover occurrence is that plant cover in the parkland is rather more homogenous; due to high anthropogenic influence (Bormann, 1987) than the forest reserve with much variability; due to ecological amplitude and environmental heterogeneity of the site (Frost, 1996) .

The plant community composition characteristics exhibited variability in pattern among virtually all the parameters. Table 3 shows that in the forest reserve and stem density of trees ≥ 5 cm Diameter at Breast Height- dbh varied between 860-1520 stems ha^{-1} with a mean of 1210.6 stems ha^{-1}. Comparatively, the parkland indicates a mean stem density of 460 stems ha^{-1}, ranging from 260 to 680 stems ha^{-1}. The mean species individuals per plot were 20 and 12 in the forest reserve and parkland respectively. The number of species per plot varied from 15 to 25 species and 9 to 16 individuals per quadrat in the forest reserve and parkland respectively. Therefore, species distribution per plot indicates a denser distribution of species and individuals in the forest reserve due to protection status than in the parkland characterised by unrestricted access (Jibrin, 2013).

Table 3: Descriptive Statistics on Plant Community Composition

Parameter	Physiographic Unit	N	Minimum	Maximum	Mean	Standard Deviation
Tree Density ha^{-1}	Forest Reserve	30	860	1520	1210.6	213.0
	Parkland	15	260	680	460	122.1
Species per Plot	Forest Reserve	30	15	25	19.8	2.455
	Parkland	15	9	16	11.8	2.336
Species Richness (Margalef)	Forest Reserve	30	1.95	3.25	2.57	0.31
	Parkland	15	1.17	2.08	1.53	0.30
Diversity Index Shanon (H′)	Forest Reserve	30	2.24	2.91	2.64	0.15
	Parkland	15	1.93	2.59	2.27	0.19

Source: Author’s field work, 2016

Figure 4a portrays that in the forest reserve and tree density exhibited downward skewness and more dispersion in the mid values; while the parkland exhibits almost symmetric data set with equal dispersion. Figures 4b and 4c show that species per plot and species richness in the forest reserve were characterised by symmetric data set, with clustering in the mid values. In contrast, data on Shannon diversity index (Figure 4d) exhibits upward positive skewness with more spread in higher values in the forest reserve while parkland was characterised by symmetric data set with clustering in mid values.

All measures of plant community composition in the study area suggest a heterogeneous spatial distribution of species both in the forest reserve and parkland. Frost (1996) pointed out that tree growth in savannah ecosystems is generally determined by edaphic factors, principally nutrient and moisture availability, landscape position, effects of fire, and anthropogenic disturbances. However, Bormann (1987) considered disturbance to be a major factor influencing landscape pattern and vegetation composition.

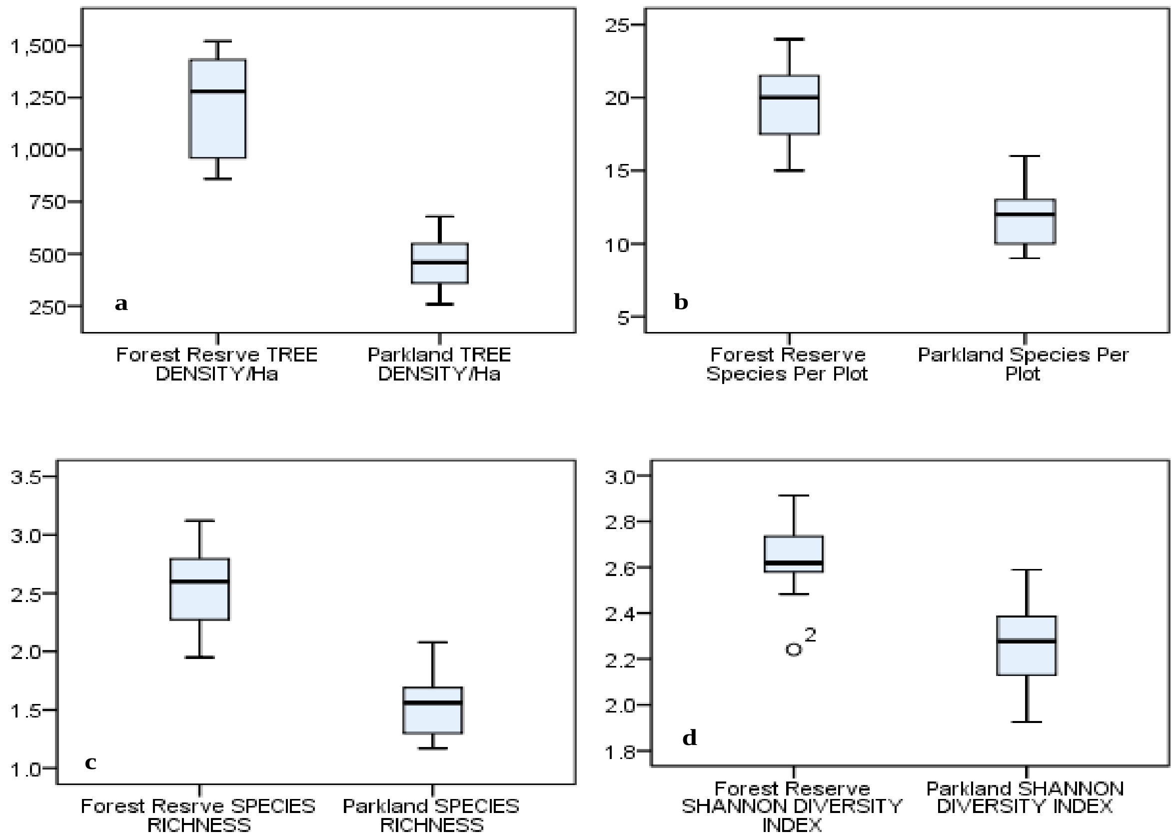

Figure 4: Spread of Data on Plant Community Composition
Source: Author's field work, 2016

Findings from this study revealed that all measured parameters of plant community structure and composition vary considerably within and among the different plant communities; which reflects the heterogeneity of plant community characteristics across the study area (Menaut *et al.*, 1995; Jibrin and Jaiyeoba, 2013). An intrinsic feature of savanna plant communities is that they do not only differ in tree density, but also in species composition (Menaut, 1983; Adejuwon and Adesina, 1992). Differences in physiological and ecological factors between savanna and forests are expected to determine the distribution of these species and consequently determine the ecological landscape.

CONCLUSION

The basic characteristic of savannah plant communities is local variation in community composition, diversity, and spatial structure. The combined effects of these factors determine the ecological landscape. Monitoring changes in the forest structure and composition through time is important for planning and management. Some changes in ecosystems are gradual and in principles detectable and predictable. Other changes are much more difficult to identify, because they are gradual; only until they reach a certain threshold at which large changes occur suddenly. By monitoring the vegetation cover change, the nature and rate of environmental degradation would be identified and proper strategies recommended towards mitigating and avoiding its devastating consequences.

The implication of the observed heterogeneity which was partly due to deforestation and forest degradation is increase in the atmospheric carbon concentration. The study recommends adoption of carbon offset projects in the study area for effective conservation of the ecological land scape; with a view to enhancing its carbon sequestration potential. This study thus presents an understanding of the complexity of ecological landscapes in the savannah woodland with a view to exploiting their climate change mitigation potentials.

ACKNOWLEDGEMENT

My profound gratitude goes to the staff of the Niger State Forestry Division, Ministry of Environment, Minna for technical support for this research. I am also indebted to the staff of the Kpashimi Forest Reserve, Lapai, Niger state who served as Field Assistants in field data collection for this study.

REFERENCES

Adejuwon, J.O. and Adesina, F.A. (1992). The Nature and the Dynamics of the Forest-Savanna Boundary in Southwestern Nigeria. In P. A. Furley, J. A. Procter and J. A. Ratter (Eds.), *Nature and Dynamics of Forest-savanna Boundaries*. First edition, Chapmann and Hall, London. pp. 331-351.

Bormann, F.H. (1987). Landscape Ecology and Air Pollution. Chapter 3, in M. Goigel Turner (ed.): *Landscape Heterogeneity and Disturbance*. Springer-Verlag, NY. Pp 7-8

Cottam G. and Curtis J.T. (1956). The Use of Distance Measurements in Phytosociological Sampling. *Ecology*, 37, 451-460.

Eyre, T. J., Kelly, A. L., and Neldner, V. J. (2006). *Methodology for the Establishment and Survey of Reference Site for Bio conditions.* Version 1.4, Environmental Protection Agency, Biodiversity Science Unit, Brisbone.

Forman, R.T.T. (1987). The Ethics of Isolation, the Spread of Disturbance, and Landscape Ecology. Chapter 12, in: M. Goigel Turner (ed.): *Landscape heterogeneity and Disturbance*. Springer-Verlag, NY.

Forman, R.T.T. and Godron, M. (1986). *Landscape Ecology*. John Wiley & Sons, New York.

Frost P. (1996). *The Ecology of Miombo Woodlands*. In: B. Campbell (Ed.): The Miombo in Transition: Woodlands and Welfare in Africa. Bogor, Indonesia: Centre for International Forestry Research (CIFOR), pp. 11 – 57.

Gareth W. (1991). *Techniques and Fieldwork in Ecology,* Collins Educational, Great Britain, pp. 36-47.

Hairiah K, Dewi S, Agus F, Velarde S, Ekadinata A, Rahayu S and van Noordwijk M, (2010). *Measuring Carbon Stocks across Land Use Systems: A Manual*. Bogor, Indonesia. World Agroforestry Centre (ICRAF), SEA Regional Office, 155 pages.

Jibrin, A., (2009). *An Assessment of the Pattern of and Changes in the Vegetation Cover Of Kpashimi Forest Reserve, Niger State*. An unpublished M.Sc. Research thesis, Department of Geography, Ahmadu Bello University, Zaria.

Jibrin, A. (2013). A Study of Variation in Physiognomic Characteristics of Guinea Savanna Vegetation, In: *Environment and Natural Resources Research* Canadian Center of Science and Education, Toronto 3(2), 52–60. doi:10.5539/enrr.v3n2p52

Jibrin, A., and Jaiyeoba, I. A. (2013). Characterization of Structural Composition and Diversity of Vegetation in the Kpashimi Forest Reserve, Niger State, Nigeria. *Journal of Geography and Geology*, Toronto 5(3), 75–87. doi:10.5539/jgg.v5n3p75 (ISSN 1916-9779 E-ISSN 1916-9787) Publisher: Canadian Center of Science and Education.

Jibrin, A. (2014). Assessment of Vegetation Cover Dynamics in the Kpashimi Forest Reserve, Niger State, Nigeria. *Zaria Geographer*, Department of Geography, Ahmadu Bello University, Zaria. 21(1), 119-131.

Keay, R.W.J. (1953). *An Outline of Nigerian Vegetation*, 2nd Edition, Government Printed, Lagos.

Margalef, D.R. (1958). Information Theory in Ecology. *General System Bulletin,* 3, 36-71

Menaut, J., Lepage, M. and Abbadie L. (1995). Savannas, Woodlands, and Dry Forests in Africa *In:* Bullock, S. H., H. A.Mooney & E. Medina (ed.), *Seasonally Dry Tropical Forests*. Cambridge University Press. pp. 64-92.

Menaut, J.C. (1983). The Vegetation of African Savannas. In F. Bourlière, (ed.), *Tropical Savannas*, 109-149. Elsevier.

Ojo, O. (1977). *The Climates of West Africa*. London: Heinemann.

Philip, M.S. (1994). *Measuring Trees and Forests*. 2nd edition. Oxford: CABI Publishing. 310pp.

Ricklefs, R. (1977). Environmental Heterogeneity and Plant Species Diversity: a Hypothesis. *American Naturalist*, 6(2), 111:376–381 DOI 10.1086/283169.

Shannon C.E., and Weiner W. (1963). *The Mathematical Theory of Communication*. Urbane (IL): University of lllinois Press.