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Plant Diversity in the Guinea Savanna Agroecological Zone in Makurdi, North Central Nigeria

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ABSTRACT

Background and Objective: Species diversity has been greatly reduced due to climate change leading to habitat loss and anthropogenic disturbances. Ecosystem degradation is known to affect plant diversity, hence the study assessed plant diversity in three ecosystems (grazing, riparian and plantation ecosystems) in Kwaghtamen Village, Makurdi Local Government Area of Benue State, Nigeria. **Materials and Methods:** In each ecosystem, 7 randomly sampled plots of 100×100 m were mapped, using line transect and all trees and shrubs were counted in each of the plots, collection of litter was done following standard practices (I m^2 quadrats). Data were collected on trees, grasses, herbs and litter. Plants were identified while type specimens were prepared following standard herbarium practices. **Results:** The relative frequency, density and important value indices varied with species and ecosystem types. *Khaya senegalensis*, *Dialium guineense* and *Gmelina arborea* were the most dominant species. The species richness in ecosystems ranged between 28 and 7 (in riparian and plantation ecosystems). Tree diversity index followed in the order H = 3.22 (riparian), H = 2.78 (grazing) and H = 1.95 (plantation), while herbs and litter diversity were highest in grazing (H= 4.0) and riparian (H = 2.8) ecosystems, respectively. **Conclusion:** This report has provided baseline information on plant species diversity in terms of distribution and richness in the three ecosystems studied. Efforts should be put in place to maintain these ecosystems, improve their plant diversity, sustainably utilize matured species of high population and conserve those with low populations as reported.

KEYWORDS

Ecosystem, diversity index, relative dominance, relative density, riparian, plantation

INTRODUCTION

Biological diversity has been defined as "the variety of life forms at all levels of biological organization and in all ecological complexes"[1]. Plant diversity is not evenly distributed; rather it varies greatly across the globe as well as within regions. Among other factors, the diversity among plants depends on climate, altitude, soils, geography and the nature of the biotic component present[2-4]. Three major benefits of plant biodiversity are utilitarian benefits, ecosystem stability and the provision of ecosystem services[5,6]. In totality, plant diversity is measured in terms of species richness and distribution. There are three levels of biological diversity: Genetic diversity, species diversity and ecosystem diversity. The different ecosystems housing diverse species of plants and animals, each interacting with themselves and the non-living

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physical environment constitute the ecosystem's diversity[5]. The study area is rich in diverse ecosystems. In the terrestrial type, there are different types scattered across the region, notably the grazing, plantation and riparian ecosystems. The structures and functions of these ecosystems are constantly being threatened by anthropogenic activities notably urbanization, climate change effects, deforestation, developmental projects and agricultural activities[7,8].

The current rate of urbanization in Makurdi, Benue State has resulted in substantial loss of habitat, biological diversity and loss of arable land, hence the need for urgent environmental sustainability[8] as well as a social development plan for the overall rural hinterland[9,10]. Baseline data on plant species richness, distribution, relative abundance and overall diversity in the selected ecosystems of the study area are lacking. It is of essence to assess and compare the level of diversity in trees, herbs and litter as a function of the health of the ecosystems. Therefore, the present study was designed to assess the plant diversity indices in three selected ecosystems (grazing, riparian and plantation) existing within the Kwaghtamen Village of Makurdi Local Government Area, Benue State, Nigeria.

MATERIALS AND METHODS

Study area: The study was carried out in Kwaghtamen Village located in Makurdi Local Government Area of Benue State (Latitude 7°44'01" N and Longitude 8°31'17" E). The choice of the location was due to the existence of diverse terrestrial ecosystems in the area. The area falls within the Guinea savanna agro-ecological zone of North Central Nigeria. Makurdi, the State Capital of Benue State, lies on the south bank of the Benue River. It experiences a tropical climate with prominent wet and dry seasons characterized by an average annual rainfall of 1290 mm and a daily temperature of 40°C maximum and a minimum of 22.5°C[11].

Sampling method: Three ecosystems (grazing, riparian and plantation ecosystems) were identified and studied in the study area within March-December, 2022. In each ecosystem, 7 randomly sampled plots of 100×100 m were mapped out using the GPS (Geographic Positioning System) following standard practices[11,12]. The line transect method was employed. In each of the plots, all trees and shrubs were counted. Girth measurement was done using the measuring tape. The 5 quadrats measuring 1×1 m were laid down at corners and the middle of each plot where counting of herbs/grasses was done. The collection of litter was done following standard practices[13,14]. Data collection on trees, grasses and litter was done in March, 2022 while data on herbs were collected in December, 2022.

Species identification: Plants were identified using a standard plant identification guide, flora and monographs of West Africa as well as internet aid[15]. Taxonomists were consulted to authenticate all unidentified plants in the Department of Botany, Joseph Sarwuan Tarka University, Makurdi, Nigeria. Collected plant specimens were prepared following standard herbarium practices[15]. Type specimens were deposited in the mini-herbarium of the above-named institution where voucher numbers were issued accordingly.

Estimation of species diversity, distribution and importance value indices: Relative frequency, relative density and relative dominance were calculated using the formula described below[16]:

$$\text{Relative frequency (RF)} = \frac{\text{Frequency of individual species}}{\text{Total frequency of all species}} \times 100$$

$$\text{Relative density (RDe)} = \frac{\text{Density of species}}{\text{Total density of all species}} \times 100$$

$$\text{Relative dominance (RDo)} = \frac{\text{Basal area of individual species}}{\text{Total basal area of all species}} \times 100$$

Basal area, BA (m^2) was calculated from DBH (Diameter at Breast Height) using the following equation:

$$BA\ (m^2) = \frac{\pi \times (DBH/2)^2}{10{,}000}$$

$$\text{Importance value index (IVI)} = RF + RDe + RDo$$

Shannon diversity ($H^{'}$) index was computed as:

$$H = -\Sigma p_i * \ln(p_i)$$

Where:

P_i = Proportion (n/N) of individuals of a particular species (n) divided by the total number of individuals (N)

In = Natural log

RESULTS

Tree species distribution and diversity: Three species distribution in the grazing plots is represented in Table 1. The 18 plant species were identified. Relative frequency was highest in *Khaya senegalensis, Parkia biglobosa, Prosopis africana* (10) and lowest in *Acacia nilotica* and some species (3.33), respectively. Relative density indicated the highest values in *Daniellia oliveri*, *Khaya senegalensis* (25.00 and 19.00) and lowest in *Acacia nilotica* and a few other species (1.00). Relative dominance shows that *Pterocarpus erinaceus* has the highest value (0.14) and lowest value observed in *Morinda lucida* (0.01). The maximum basal area was 24608.93 m^2 in *Pterocarpus erinaceus* and the minimum of (1618.92 m^2) in *Morinda lucida*. Importance value indices indicated a rangeof 4.34-35.04 (*Daniella oliveri)* showing maximum value (35.04) and *Anogeissus leiocarpa* showing minimum value.

In the riparian vegetation (Table 2), 28 tree plant species were identified. The relative frequency was highest in *Anthocleista djalonensis* and *Berlina diversifolia,* (7.69) and lowest in *Acacia polyacantha* and some other species (2.56). Relative density ranged from 22.03 to 0.85 in *Dialium guineense* and lowest in *Acacia polyacantha,* respectively. *Daniellia ogea* had the highest relative dominance while

Table 1: Species distribution in a grazing ecosystem at Kwaghtamen, Makurdi, Nigeria (2022)

Species	No. Sp.	Freq.	Basal area	Pi	In (Pi)	Pi*In (Pi)	Rel. freq	Rel. Den.	Rel. Dom.	IVI
Acacia nilotica	1	33	12869.63	0.03	-3.40	-0.11	3.33	1.00	0.07	4.40
Acacia polyacantha	5	67	4657.39	0.07	-2.71	-0.18	6.67	5.00	0.03	11.69
Anogeissus leiocarpa	1	33	1885.99	0.03	-3.40	-0.11	3.33	1.00	0.01	4.34
Azadirachta indica	1	33	12869.63	0.03	-3.40	-0.11	3.33	1.00	0.07	4.40
Daniellia oliveri	25	100	7755.08	0.10	-2.30	-0.23	10.00	25.00	0.04	35.04
Ficus sycomorus	1	33	11311.20	0.03	-3.40	-0.11	3.33	1.00	0.06	4.40
Ficus trichopoda	1	33	17205.59	0.03	-3.40	-0.11	3.33	1.00	0.09	4.43
Gmelina arborea	2	67	3456.60	0.07	-2.71	-0.18	6.67	2.00	0.02	8.69
Khaya senegalensis	19	100	11600.47	0.10	-2.30	-0.23	10.00	19.00	0.06	29.06
Lannea schimperi	2	33	16731.55	0.03	-3.40	-0.11	3.33	2.00	0.09	5.43
Morinda lucida	2	33	1618.92	0.03	-3.40	-0.11	3.33	2.00	0.01	5.34
Parkia biglobosa	18	100	22630.17	0.10	-2.30	-0.23	10.00	18.00	0.12	28.12
Prosopis africana	10	100	19037.30	0.10	-2.30	-0.23	10.00	10.00	0.11	20.11
Pterocarpus erinaceus	1	33	24608.93	0.03	-3.40	-0.11	3.33	1.00	0.14	4.47
Sarcocephalus latifolius	6	67	3202.22	0.07	-2.71	-0.18	6.67	6.00	0.02	12.68
Sterculia setigera	2	33	1816.47	0.03	-3.40	-0.11	3.33	2.00	0.01	5.34
Vitellaria paradoxa	1	33	3848.95	0.03	-3.40	-0.11	3.33	1.00	0.02	4.35
Vitex doniana	2	67	4124.27	0.07	-2.71	-0.18	6.67	2.00	0.02	8.69

Pi: Proportion (n/N) of individuals of a particular species (n) divided by the total number of individuals (N), In: Natural log, IVI: Importance value indices, No. Sp.: Number of species, Freq.: Frequency, Rel. freq.: Relative frequency, Rel. Den.: Relative density and Rel. Dom.: Relative dominance

Table 2: Species distribution in a Riparian ecosystem at Kwaghtamen, Makurdi, Nigeria (2022)

Species	No. Sp.	Freq.	Basal area	Pi	In(Pi)	Pi*In(Pi)	Rel. freq	Rel. Den.	Rel. Dom.	IVI
Acacia polyacantha	1	33	2043.09	0.03	-3.66	-0.09	2.56	0.85	0.01	3.42
Annona senegalensis	2	33	1162.54	0.03	-3.66	-0.09	2.56	1.69	0.01	4.26
Anogeissus leiocarpa	1	33	1134.26	0.03	-3.66	-0.09	2.56	0.85	0.01	3.42
Anthocleista djalonensis	12	100	3125.77	0.08	-2.56	-0.20	7.69	10.17	0.01	17.88
Berlina diversifolia	14	100	10555.21	0.08	-2.56	-0.20	7.69	11.86	0.05	19.61
Daniellia ogea	2	33	40158.69	0.03	-3.66	-0.09	2.56	1.69	0.19	4.45
Daniellia oliveri	4	33	9457.82	0.03	-3.66	-0.09	2.56	3.39	0.04	6.00
Dialium guineense	26	100	7635.64	0.08	-2.56	-0.20	7.69	22.03	0.04	29.76
Diospyros mespiliformis	2	67	7165.33	0.05	-2.97	-0.15	5.13	1.69	0.03	6.86
Entada africana	1	33	1018.01	0.03	-3.66	-0.09	2.56	0.85	0.00	3.42
Funtumia africana	2	33	4392.91	0.03	-3.66	-0.09	2.56	1.69	0.02	4.28
Gmelina arborea	2	33	688.49	0.03	-3.66	-0.09	2.56	1.69	0.00	4.26
Ilex vomitoria	1	33	3632.15	0.03	-3.66	-0.09	2.56	0.85	0.02	3.43
Khaya senegalensis	1	33	5411.31	0.03	-3.66	-0.09	2.56	0.85	0.03	3.44
Lannea schimperi	3	67	8657.52	0.05	-2.97	-0.15	5.13	2.54	0.04	7.71
Parinari curatellifolia	2	33	2961.34	0.03	-3.66	-0.09	2.56	1.69	0.01	4.27
Parkia biglobosa	1	33	19609.22	0.03	-3.66	-0.09	2.56	0.85	0.09	3.50
Piliostigma thonningii	1	33	1809.79	0.03	-3.66	-0.09	2.56	0.85	0.01	3.42
Prosopis africana	1	33	1194.75	0.03	-3.66	-0.09	2.56	0.85	0.01	3.42
Pterocarpus santalinoides	15	67	12501.91	0.05	-2.97	-0.15	5.13	12.71	0.06	17.90
Rauvolfia vomitoria	1	33	1256.80	0.03	-3.66	-0.09	2.56	0.85	0.01	3.42
Sarcocephalus latifolius	1	33	962.24	0.03	-3.66	-0.09	2.56	0.85	0.00	3.42
Sterculia setigera	1	33	12077.85	0.03	-3.66	-0.09	2.56	0.85	0.06	3.47
Terminalia avicennioides	3	33	3345.45	0.03	-3.66	-0.09	2.56	2.54	0.02	5.12
Unknown similar to 1	1	33	6082.91	0.03	-3.66	-0.09	2.56	0.85	0.03	3.44
Unknown tree spp 1	1	33	17205.59	0.03	-3.66	-0.09	2.56	0.85	0.08	3.49
Unknown tree spp2	2	33	17820.25	0.03	-3.66	-0.09	2.56	1.69	0.08	4.34
Vitex doniana	14	100	11103.04	0.08	-2.56	-0.20	7.69	11.86	0.05	19.61

Pi: Proportion (n/N) of individuals of a particular species (n) divided by the total number of individuals (N), In: Natural log, IVI: Importance value indices, No. Sp.: Number of species, Freq.: Frequency, Rel. freq.: Relative frequency, Rel. Den.: Relative density and Rel. Dom.: Relative dominance

Acacia polyacantha, *Annona senegalensis*, *Anogeissus leiocarpa*, *Berlina diversifolia*, *Parinari curatellifolia*, *Piliostigma thonningii* and *Prosopis africana*, all had the least. Basal area was highest in *Parkia biglobosa,* (19609.22 m^2) while *Gmelina arborea* recorded the lowest value (688.49 m^2). Importance value indices reviewed *Dialium guineense* with the highest value (29.76) and *Acacia polyacantha*, *Anogeissus leiocarpa*, *Entada africana*, *Piliostigma thonningii*, *Prosopis africana*, *Rauwolfia vomitoria* and *Sarcocephalus latifolius* recording the lowest value (3.42).

Table 3 gives the tree species distribution in the plantation. The 7 plant species were identified. Relative frequency of 14.29 was recorded for all the species. *Gmelina arborea* recorded the highest relative dominance (80.00) while lowest values were observed in *Erythrina senegalensis*, *Prosopis africana*, *Vitex doniana* (0.95) respectively. *Prosopis africana,* was the dominant species followed by *Parkia biglobosa,* (0.16), *Daniellia oliveri* (0.16) and *Gmelina arborea*. *Prosopis africana* recorded the highest basal area (24055.94 m^2) with *Tectona grandis* having the lowest value (3012.00 m^2). Importance value indices indicated *Gmelina arborea* with the highest value (94.38) and *Vitex doniana* with the lowest value (15.36). Across the ecosystems, tree diversity, evenness and richness were highest in riparian compared to grazing and plantations plot (Table 4).

Herbs diversity: The herbs diversity index in grazing, plantation and riparian plots shows that grazing plots recorded the highest level of diversity (4.00) followed by riparian (3.00) with plantation being the least with a value of 2.00. Species richness indicated maximum value in grazing ecosystem (44.00) followed by riparian plot (31.00) while plantation displayed the least value (15.00). Species evenness ranged from 0.08-0.12 with plantation recording the maximum value (0.12) followed by riparian (0.10) and grazing having the minimum value (0.08) (Fig. 1).

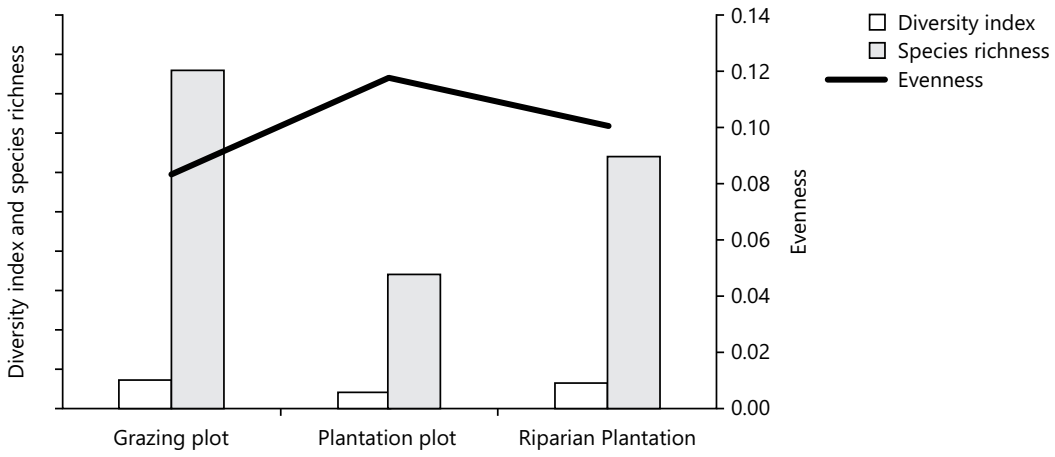

Fig. 1: Herbs species diversity index, species richness and evenness plots

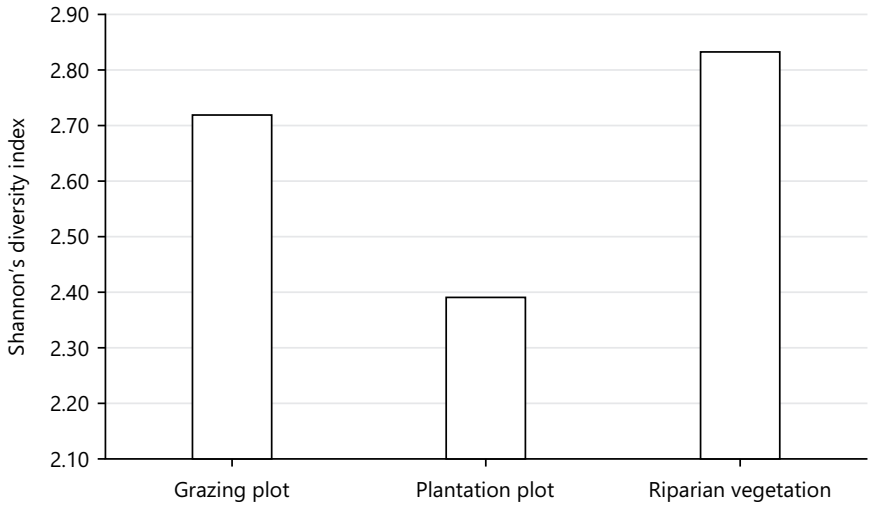

Fig. 2: Litter diversity studied in the three ecosystems

Table 3: Species distribution in a plantation ecosystem at Kwaghtamen, Makurdi, Nigeria (2022)

Species	No. Sp.	Freq.	Basal area	Pi	In(Pi)	Pi*In(Pi)	Rel. freq	Rel. Den.	Rel. Dom.	IVI
Daniellia oliveri	4	33	12711.36	0.14	-1.95	-0.28	14.29	3.81	0.16	18.25
Erythrina senegalensis	1	33	9332.53	0.14	-1.95	-0.28	14.29	0.95	0.12	15.36
Gmelina arborea	84	33	7711.58	0.14	-1.95	-0.28	14.29	80.00	0.10	94.38
Parkia biglobosa	2	33	13077.01	0.14	-1.95	-0.28	14.29	1.90	0.16	16.35
Prosopis africana	1	33	24055.94	0.14	-1.95	-0.28	14.29	0.95	0.30	15.54
Tectona grandis	12	33	3012.00	0.14	-1.95	-0.28	14.29	11.43	0.04	25.75
Vitex doniana	1	33	9678.15	0.14	-1.95	-0.28	14.29	0.95	0.12	15.36

Pi: Proportion (n/N) of individuals of a particular species (n) divided by the total number of individuals (N), In: Natural log and IVI: Importance value indices

Table 4: Tree diversity indices, evenness and richness studied in the three ecosystems

Vegetation	Diversity index	Evenness	Species richness
Grazing plot	2.78	0.03	100
Riparian plot	3.22	0.12	28
Plantation plot	-1.95	-0.42	105

Litter diversity: The Shannon index was used to describe litter diversity across the study area. Riparian ecosystem displayed the highest level of litter diversity (2.80) followed by grazing (2.70) and plantation with the least value of (2.40) (Fig. 2).

DISCUSSION

The study revealed more trees and higher tree diversity in the riparian ecosystem compared to other study areas indicating, higher floristic heterogeneity in the riparian areas. The variety of tree species documented may be attributed to the protection and prevention of anthropogenic activities like hunting and deforestation in the ecosystem. While species evenness was higher in the riparian ecosystems than in plantation and grazing ecosystems, respectively, this may be attributed to a high degree of nutrients as a result of the high rate of organic decomposition and favorable environmental conditions[17]. The presence of rapid river flow in the riparian ecosystem during the rainy season and the stagnant nature of the river in the dry season across this ecosystem offers a unique microclimate that is suitable for the accumulation of organic matter, growth and regeneration of tree species[17,18]. The distribution frequency and relative density of tree species in the different ecosystem types were variable. Higher density was observed in plantations where multipurpose trees are grown including *Daniellia oliveri*, *Erythrina senegalensis*, *Gmelina arborea*, *Parkia biglobosa*, *Prosopis africana*, *Tectona grandis* and *Vitex doniana*. The high relative frequency, dominance and importance value indices in the plantation ecosystem suggest minimal human and animal interference in the ecosystem probably due to effective protection practices. Plantation has been suggested as an effective way to restore degraded ecosystems, also helping to mitigate elevated carbon dioxide and hence contribute toward the reduction of global warming[19].

Riparian zones have been reported as one of the habitats most threatened by human activities[20]. Land use changes have affected the dynamics of riparian vegetation and its ability to support biological diversity[21,22] thus affecting the ecosystem functionality and its services in grazing sites[6]. The rate of litter accumulation in grazing plots may be attributed to season and influence of environmental variables[23]. Litterfall and accumulation exhibit seasonality with dry and wet seasons this seasonality is the general pattern of litterfall in the tropics and may be attributable to the influence of environmental variables (rainfall, temperature and wind speed) in the study site[23].

The diversity of litter was high in the riparian ecosystem followed by grazing and plantation plots. The high rate of diversity may be due to the time of the research and the moisture content of the ecosystem that discourages anthropogenic activities such as bush burning and hunting[18]. The higher diversity and richness of herbs in the grazing ecosystem may be probably due to grazing activities in the grazing ecosystem that promote the growth of herbaceous layers. Also, the grazing activities may have stimulated high herb diversity and species richness. This view aligned with the report by Dybala *et al*.[22] and Angassa[24] who found that light to moderate grazing increased herbaceous species diversity. The present study found that species evenness was higher in plantation ecosystems, followed by riparian and then grazing. This higher evenness of herbs may be attributed to regulated grazing and human interference in the plantation.

CONCLUSION

The three ecosystems differed with respect to the evaluated parameters of diversity. *Khaya senegalensis*, *Dialium guineense* and *Gmelina arborea* were ranked highest in the grazing, riparian and plantation ecosystems, respectively based on their relative frequency, relative density and important value indices. The riparian ecosystem had the highest tree and litter diversity while the grazing ecosystem had the highest herb diversity. This report has provided baseline information on the diversity of plant species in terms of distribution and richness in the three ecosystems studied. Efforts should be put in place to maintain these ecosystems, improve their plant diversity, sustainably utilize the matured species with high populations and conserve those with low populations as reported.

SIGNIFICANCE STATEMENT

The research focused on assessing the diversity, relative abundance and importance value indices of the plants in the study area, following increased grazing activities and anthropogenic pressures on land due to insecurity in neighboring towns. Results showed that *Khaya senegalensis*, *Dialium guineense* and *Gmelina arborea* were the most abundant species in the area. Tree diversity, importance value indices and

litter diversity were highest in the riparian ecosystem, while the grazing ecosystem had the highest herb diversity. This will provide insight into the ecological health of the study area and useful information for effective future planning by policymakers.

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