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Angiosperm Species Diversity in Three Riparian Habitats Influenced by Anthropogenic Activities in Lafia, North Central, Nigeria

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Abstract: This research was carried out to investigate the plant species diversity of three riparian habitats along three water bodies influenced by different anthropogenic activities in Lafia, Nigeria. The three riparian study sites were divided into three strata along gradient from effluent point source from which samples were taken between May 2016 and December 2016. Plant species were identified and various plant population indices such as species richness, evenness, density and diversity were determined using standard methods. The plant samples were analysed for heavy metal contents. The physiochemical parameters such as temperature, pH, total dissolved solid and conductivity of the sediments were also determined. A total of 782 individual plants were counted belonging to six species and five families. *Eleucine indica, Calapogomium mucronoides* and *Gompherena celosiodes* were the most abundant plant species. The values of the pH, temperature, total dissolved solid and conductivity of the sediments were found to be within the limits prescribed by International Sediment Quality Guideline. Hence it is concluded that the studied sites were low in species diversities which could be as a result of the local human activities going on at these sites.

Keywords: Anthropogenic, Lafia, Riparian habitat, Species diversity

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1. Introduction

Riparian vegetation is described as vegetation found along the borders of streams, lakes, reservoirs, springs and seeps (Dudgeon et al., 2006; Keeton et al., 2007; Mendez-Toribio et al., 2014; Roy et al., 2006; You et al., 2015). Its wet soils and high water table creates a suitable environment for growth of some water-loving plants and the vegetations are usually greenish throughout the year (Robert, 1994). Destruction of ecosystems by anthropogenic activities as a result of his pursuit for survival has created a world in which delicate ecological balance of flora has been altered, in many instances causing the extinction of entire species due to destruction of habitat (Gonzalez et al., 2016; Newbold et al., 2015; Newbold et al., 2016; Venter et al., 2016).

Humans have greatly affected the rates of supply of the macro nutrients that limit the productivity, composition, and diversity of aquatic and riparian ecosystems (Alemu et al., 2017; Allan et al., 2015; Vitousek et al., 1997; Isbell et al., 2017; Vallend et al., 2017; You et al., 2015). Moreover, numerous environmental impacts of anthropogenic activities are projected to increase and much stronger ecological consequences. (Cardinale et al., 2012; Tilman et al., 2001; Tilman et al., 2017). Biodiversity losses in the tropical rain forest and some other plant communities have been attributed mainly to human activities such as habitat destruction, introduction of invasive species and over-exploitation of natural resources (Hautier et al., 2015; Lowrance, 1998; Millenium Ecosystem Assessment, 2005; Scherber et al., 2010). Species diversity of a community is a genuine tool for establishing the influence of biotic as well as abiotic factors, the state of succession and environmental stability (Garssen et al., 2014; Garssen et al., 2015; Misra, 1989; Roossinck and Garcia-Arenal, 2015; Steiger et al., 2005; Wardle et al., 2011).

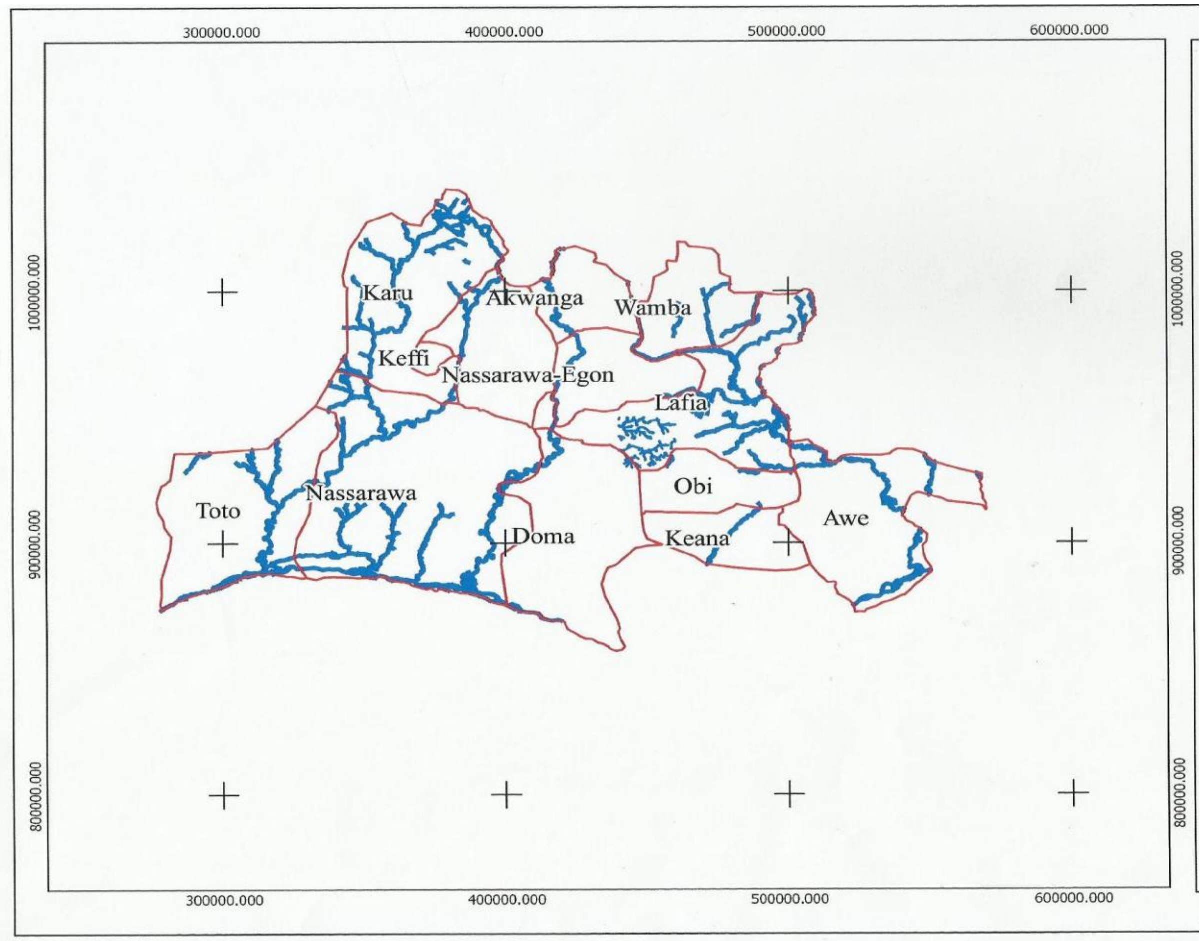

Fig. 1: Map of Nasarawa State showing water bodies (Source: Nasarawa Geographic Information Services).

Table 1. Geographical coordinates and description of the sites

S. No.	Site location	Longitude	Latitude
1	Shabu, Lafia	08°56.655'N	008°55.059'E
2	Permanent site, Federal University Lafia	08°28.379'N	008°28.379'E
3	Doma road, Lafia	08°49.012'N	008°85.103'E

Restoration of riparian zones is of great ecological importance and major initiative for the improvement of degraded and deforested wetland ecosystem (Catford et al., 2013; Hession et al., 2000; Lorion and Kennedy, 2009; Lyons et al., 2000; Nava-Lopez et al., 2016; Pusey and Arthington, 2003; Roy et al., 2006). This study investigated the effects of anthropogenic activities on the plants diversity along three water bodies in Lafia, Nasarawa State, Nigeria. Commercial motor cycle riders (Okada riders in Nigeria) frequently visit these water bodies for washing of their motor cycles. In addition, the sites are greatly influenced by dumping of domestic wastes into these water bodies which pose serious threats to aquatic flora and surrounding vegetations.

2. Materials and Methods

2.1. Study Location

The three water bodies are located in Lafia, Nasarawa State of Nigeria (Fig. 1). The description of locations and coordinates of the three sites are shown in Table 1. They are natural habitats that have been greatly influenced by anthropogenic activities such as washing of vehicles and cassava processing and dumping of refuse over the last five years. The geographic coordinates of the three sites were taken using a Global Positioning System (GPS) (Garmin 12XL, USA) device.

2.2. Collection of Samples

Stratified and random sampling techniques were employed in this study. Each water body was divided into three strata A, B and C along gradient from the effluent point source. A meter tape was used to measure 10 metres distance between each stratum and 3 metres away from the water bank. Plant samples were collected randomly in 3 replicates from each stratum between May 2016 and December 2016. The Plants collected were identified and prepared for chemical analysis.

2.3. Plant Diversity Study

The abundance and diversities of plants species found at each stratum of water bodies were determined and compared. In each stratum, a quadrant of size 1.5m x 1.5m was used as a random sampling technique. The quadrant was thrown five times and the mean of each value was determined. Some of the parameters determined include:

$$Density = \frac{Number\ of\ plants}{Area\ of\ quadrant\ m-^{2}} \quad [1]$$

$$Species\ diversity, H = \sum pi\ (Inpi) \quad [2]$$

Where pi = ni/N
ni is the number of individuals in the ith species
N is total number of individuals

$$Species\ Richness\ (Margalef\ index) = \frac{S}{\sqrt{N}} \quad [3]$$

Where S is total number of Species

$$Species\ evenness = \frac{H}{Log\ S} \quad [4]$$

Where H is species diversity

2.4. Determination of Physicochemical Characteristics of Sediments

Sediment physicochemical parameters were determined using a hand held pH meter (Combo Hanna) for three weeks as described by Ebigwai et al. (2014). Some parameters analyzed are pH, temperature, conductivity and Total Dissolved Solids.

2.5. Chemical Analysis of Samples

In order to ascertain the level of toxicity in the plants collected in each water body, the collected samples were in turn taken to the laboratory for chemical analysis using standard method (Tarley et al., 2001). Plants samples were weighed inside a crucible and were arranged in a furnace and heated at 70^{o}C for 4 hours. The ash sample was allowed to be cooled before bringing it out of the furnace for extraction. The ash plant sample inside the crucible was transfer to centrifuge tubes and rinsed with 5 ml of ultra pure water. Seven and half (7.5) ml of *Aqua regia* was dispensed again and rinse inside the centrifuge tube. The centrifuge was covered and shook on a shaker for 5mins. The digest was analyzed for Pb and Zn, using an Atomic Absorption Spectrophotometer, AAS (GBC scientific equipment Sens AA, Melbourne, Australia).

2.6. Data Analysis

All quantitative data obtained were entered on SPSS (version 17) and analyzed using one way analysis of variance at 0.05% significant level.

3. Results

3.1. Study Locations and Plants Identified

Six plant species belonging to five families were identified in all the three sites with members of the Family Fabaceae represented by two species (Table 2). Also, the growth habit of the species revealed that there were shrub species, sedge, floater and creeper (one each), and, two herbs. A total of 782 individuals were counted during the study. *Eleucine indica*, *Calapogomium mucronoides* and *Gompherena celosiodes* were the most abundant and most frequent in the study sites.

Table 2: Floral checklist in study sites

S/N	Species	Family	Growth Habit	Shabu (Site 1)	Permanent site (Site 2)	Doma (Site 3)	IUCN 2016 status	Alien or Invasive status in Nigeria
1	Calopogonium *mucronoides*	Fabaceae	Herb	21	7	8	NE	Invasive
2	*Eichornia crassipes*	Pontederiaceae	Herb	11	0	0	NE	Not invasive or alien to Nigeria
3	*Eleusine indica*	Poaceae	Grass	23	23	14	NE	Not invasive or alien to Nigeria
4	*Gompherena celosiodes*	Amaranthaceae	Herb	12	7	13	NE	Not invasive or alien to Nigeria
5	*Mimosa pigra*	Fabaceae	Shrub	0	2	0	LC	invasive
6	*Nympheae lotus*	Nymphaceae	Floating Hydrophyte	4	0	0	NE	Not invasive or alien to Nigeria

LC, Least Concern; NE, Not Evaluated

Table 3. Species richness, density, evenness and diversity of site 1 & 2.

	Species richness		Density		Species evenness		Plant diversity	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Stratum A	0.650^{ba} ± 0.03	0.436^{a} ± 0.11	7.111^{a} ± 0.81	8.800^{b} ± 0.65	2.246^{d} ± 1.39	1.379^{a} ± 0.73	0.389^{c} ± 0.11	0.503^{c} ± 0.22
Stratum B	0.531^{bd} ± 0.07	0.504^{a} ± 0.05	7.64^{a} ± 1.31	8.622^{b} ± 0.59	1.087^{d} ± 0.29	1.928^{a} ± 0.24	0.421^{c} ± 0.12	0.634^{c} ± 0.06
Stratum C	0.392^{cd} ± 0.05	0.254^{a} ± 0.11	8.88^{a} ± 1.43	4.089^{a} ± 1.68	0.693^{d} ± 0.49	0.790^{a} ± 0.49	0.250^{c} ± 0.15	0.238^{c} ± 0.15

Values (± SE) with the same superscript across column are not significantly different ($P \leq 0.05$). Site 1, Shabu, Lafia; Site 2, Permanent site, Federal University Lafia.

The other three species were observed in only one site while *Mimosa pigra* was the least abundant among the studied species. Two species, *Mimosa pigra* and *Calapogonium mucronoides* are invasive to Nigeria. Also, none of the species is classed as threatened in the IUCN 2016 version 1.

3.2 Plant Diversity Study

As shown in Table 3, the species richness of Site 1 decreases significantly from stratum A to C i.e. (A > B > C). Also the density of plants in stratum C is higher than strata A and B. The species evenness of stratum A is higher than strata B and C and follows this trend: A > B > C. In Site 2, the differences in the species richness across the three strata are not significant (Table 3). The density of plants increases from stratum A to C (A < B < C) and are significantly different. The species evenness and diversity are not significantly different ($P \leq 0.05$) across the three strata. Also in Site 3, the differences in the species richness, evenness, density and diversity across the three strata are not significant (Table 4).

3.3 Physico-Chemical Parameters of Sediment

Table 5 showed the results obtained for the sediment physic-chemical parameters. The mean pH concentration ranged from 6.42 to 6.57 while conductivity values ranged from 40.33 to 310.33 µS/cm. The temperature of the sediment ranged from 29.70^{o}C to 31.23^{o}C. These concentrations were within the limits prescribed by International Sediment Quality Guideline. Similarly, nitrate ion concentration ranged from 0.29mg/l to 0.31mg/l in samples collected at the three sites. The concentration of Potassium fluctuates between 0.001 and 0.002 mg/l at the three sampling locations. Also, the concentration of sodium ranged from 0.67 to 2.33mg/l in samples collected at the sites. Regulatory limits do not exist for these parameters.

3.4 Heavy Metals in Plant Species

As shown in Fig. 2, all the concentrations of Pb and Zn obtained in the three sites were within the ISGV regulatory limits of 50ppm for Pb and 120 – 540 ppm for Zinc.

4. Discussion

Millennium Ecosystem Assessment (2005) has described direct impact of human activities such as habitat destruction, land use change, invasive species and over-exploitation coupled with indirect effects of human activities as the primary modern cause of tropical plant biodiversity loss. Our results are in agreement with the findings of Kelvin and Lewis (1994). They reported that destruction of enormous tracts of natural vegetation, excavated large areas of water bodies are linked with human activities.

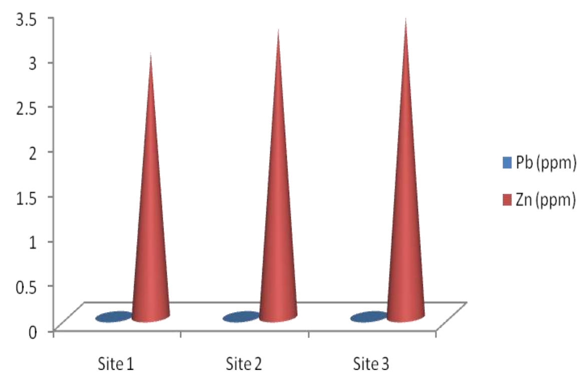

Fig. 2: the concentration of Pb and Zn in the censored plant species. Site 1, Shabu, Lafia; Site 2, Permanent site, Federal University Lafia; Site 3, Doma road, Lafia.

Table 4: Species richness, density, evenness and plant diversity of site 3.

	Species richness	Density	Species evenness	Plant diversity
Stratum A	0.495^{a} ± 0.07	8.444^{b} ± 0.67	1.258^{e} ± 0.48	0.647^{d} ± 0.15
Stratum B	0.403^{a} ± 0.07	10.311^{b} ± 1.25	1.178^{e} ± 0.49	0.685^{d} ± 0.18
Stratum C	0.512^{a} ± 0.03	8.444^{b} ± 2.31	1.833^{e} ± 0.18	0.663^{d} ± 0.06

Values (± SE) with the same superscript across column are not significantly different ($P \leq 0.05$).

Table 5: Chemical parameters of sediments from study sites

Parameter	Site 1	Site 2	Site 3	ISQG
pH (Water) @ 21.8^{O}C	6.42 ± 0.0	6.57 ± 0.02	6.57 ± 0.02	6.0-9.0
Conductivity (µS/Cm)	40.33 ± 0.33	67.33 ± 1.45	310.33 ± 0.88	NA
Temperature (^{O}C)	31.23 ± 0.03	29.70 ± 0.40	30.10 ± 0.0	40
Total Dissolved Solids (mg/l)	22.33 ± 0.88	34.33 ± 0.33	113.33 ± 2.02	NA
Nitrate (mg/l)	0.31 ± 0.12	0.29 ± 0.12	0.29 ± 0.11	NA
Phosphate (mg/l)	0.05 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	NA
Potassium (mg/kg)	0.002 ± 0.0	0.001 ± 0.0	0.001 ± 0.0	NA
Sodium (mg/Kg)	0.67 ± 0.67	0.83 ± 0.83	2.33 ± 0.08	NA

Values represent mean ± Standard Error, NA; Not Available, ND; Non-detectable, ISQG; International Sediment Quality Guideline. Site 1, Shabu, Lafia; Site 2, Permanent site, Federal University Lafia; Site 3, Doma road, Lafia.

Land areas exposed to seasonal or episodic flooding challenges have demonstrated species diversity similar to point of origin (Ebigwai et al., 2014). Similarly, Obadoni and Ochuko (2001) showed differences in floral assemblages in same environment exposed to differential extent of flooding regime. In this study, contiguous riparian areas to the water bodies exhibited same floristic resources. This was demonstrated in the occurrence of *Eichhornia crassipies* inside the water bodies and three meters (3m) away from the shore. The effect of the flooding episode on this species was further confirmed by the absence of this species at higher grounds in the riparian habitat, a metre away from the Maximum Flooding Surface (MFS)

Maximum Flooding Surface which is the extent of water shed on land environment or continental shelf (Ebigwai, 2014). The MFS at the Riparian habitat at the Site 2 seemed to be marked by the presence of *Mimosa pigra*. This observation was confirmed after repeated field surveys showed a distance of 5 - 10 metres after each successive flooding regime as against the presence and abundance of *Mimosa* after the 10 metres mark. This suggestion was further strengthened by the absence of this species in the water body. Since, *Mimosa pigra* is an invasive species, its presence would have been observed within the 5 – 10 metres mark, lending further credence to the aforementioned distance as the maximum flooding surface.

Calopogonium mucronoides is a creeper of the modified forest habitat (Odugbemi, 2006). Its presence in riparian habitats has been poorly reported. Repeated observed flooding sequence in the riparian habitats of sites 2 and 3 showed a maximum flooding surface corresponding to the presence and abundance of *Calapogonium mucronoides* at a distance of 4.5m for the former and 2m for the latter. The shortest flooding distance observed in the riparian habitat at site 3 could be attributed to the higher Pb and Zn accumulation that was reported in this study. The higher concentration of Zn and Pb reported in this environment relate more closely to higher pollution load into the nearby plants than do the relative quantity of the heavy metals in the other sites under discussion. This suggestion strongly relates with the nitrate, potash, phosphate and sodium ion concentrations at riparian habitat of site 3. The relatively shorter flooding distance would have accounted for the relatively high organic ions in this area.

Results from this study show that human activities have immensely affected plant diversity in the three study areas. The differences observed in the species richness clearly show that the farther the stratum from effluent point source, the lesser the species richness. According to Clipp and Anderson (2014), riparian habitats with little or no human interferences usually have high plant species diversity. The chemical analysis of site 1 show different concentration of some chemical elements as a result of usage of detergents and other chemicals in washing vehicles in the water body. The concentrations of heavy metals (Zn and Pb) observed in the plants samples as compared with the WHO standards are below the recommended threshold levels (Amjad et al., 2010; WHO, 1999;). According to Giliba et al. (2011), climatic, edaphic variability and anthropogenic activities are factors associated with differences in species richness in an environment. This is in agreement with this work where the species richness differs from stratum A to C as a result reduction in the discharge of chemicals from washing of vehicles from the point source. Chidumayo (1989) also stated that human activities play important role in the ecosystem dynamics. According to Barbour et al.

(1999), an ecosystem with species diversity greater than 2 is regarded as a medium to high diverse ecosystem in terms of species. In each of the three sites, the species diversities is less than 2 meaning that the three study sites are less diverse in terms of species.

According to Krebs (1989), species diversity index increases with the number of species in the community. This clearly indicates that the plant communities in these sites have few number of plant species. This can be attributed to the disruption of the ecosystem caused by the washing of vehicles, dumping of toxic domestic wastes and other human activities. However, the profound effects of human activities on these environments are still within regulatory limits (WHO, 1999). Nonetheless, the continuous open dump method in use in these water bodies may result in heavy metal build up in consumables which may elicit major public health concerns.

5. Conclusion

Conclusively, from the results obtained in this work, the three sites have shown lower species diversity which is a function of the species richness and species evenness. This indicated that these study sites have been negatively affected by the anthropogenic activities thereby making them to be poor in plant species diversity.

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Author's contribution: G.F.A. was responsible for literature review, field work, manuscript writing and revision process; A.O. was involved in field work and data analysis; F.J. assisted with data collection. All authors read and approved manuscript.

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