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Diversity Indices of Crude Oil Impacted Vegetation

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ABSTRACT

Understanding of diversity indices helps measurable description and vegetation communities' comparison, laying the ground work for reliable strategies for conservation and management. This study assessed the diversity indices of vegetation in crude oil-impacted plots and an uncontaminated control site in K-Dere community, Gokana Local Government. Using 40 m × 40 m quadrats, plant species composition was recorded in three oil-impacted plots (Plots 1–3) and one control plot. Diversity was evaluated using taxa richness index, Shannon–Wiener index, Simpson's index, dominance, and Pielou's evenness. A total of 41 plant taxa from 21 families were recorded across all plots. Taxa richness ranged from 38 (Plots 1 and 2) to 40 (control). Dominance values were consistently low (0.03283–0.04577), indicating no single species monopolised community resources. Simpson's diversity ranged from 0.9542 (Plot 1) to 0.9672 (Plot 3); the Shannon–Weaver index increased progressively from 3.316 in Plot 1 to 3.54 in Plot 3, with the control recording 3.502. Evenness values (0.7248–0.8836) indicated broadly uniform species representation. These results showed that both contaminated and uncontaminated (control) areas are within a narrow margin, indicating a relatively similar level of species richness and evenness across all sites.

KEYWORDS: Biodiversity indices, crude oil pollution, Taxa richness (S), Dominance (D), Simpson's Diversity (1 – D), Shannon–Wiener index (H), and Evenness (e^H/S)

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Introduction

Vegetation is the functional array of plants that exist in the landscape, plant collection and the ground cover they provide. The term vegetation is used more generally and expansively than "flora," and typically refers to broader spatial scale than the term "flora" (Tanee *et al*. 2023). Vegetation may be regarded as an environmental-factor index because it responds to changes in environmental conditions (Tanee *et al*. 2023).

Species diversity is a biodiversity key component, summing up richness and evenness of species into one metric that is meaningful. High diversity of species is generally described as ecosystem health and stability indicator. It encourages security of food, enhances resistance to environmental stress and increases ecological services like sequestration of carbon, purification of carbon and pollination (Tanee, et al., 2023). Understanding of diversity indices helps measurable description and vegetation communities' comparison, laying the ground work for reliable strategies for conservation and management.

Crude oil pollution is a general environmental concern in the Niger Delta area of Nigeria, negatively impacting chemistry of soil, communities of microorganism, and establishment of plant. However, systematic quantitative research on how pollution changes diversity indices of vegetation remain limited in K-Dere community in Gokhana Local Government Area. Index of diversity proposed by Simpson

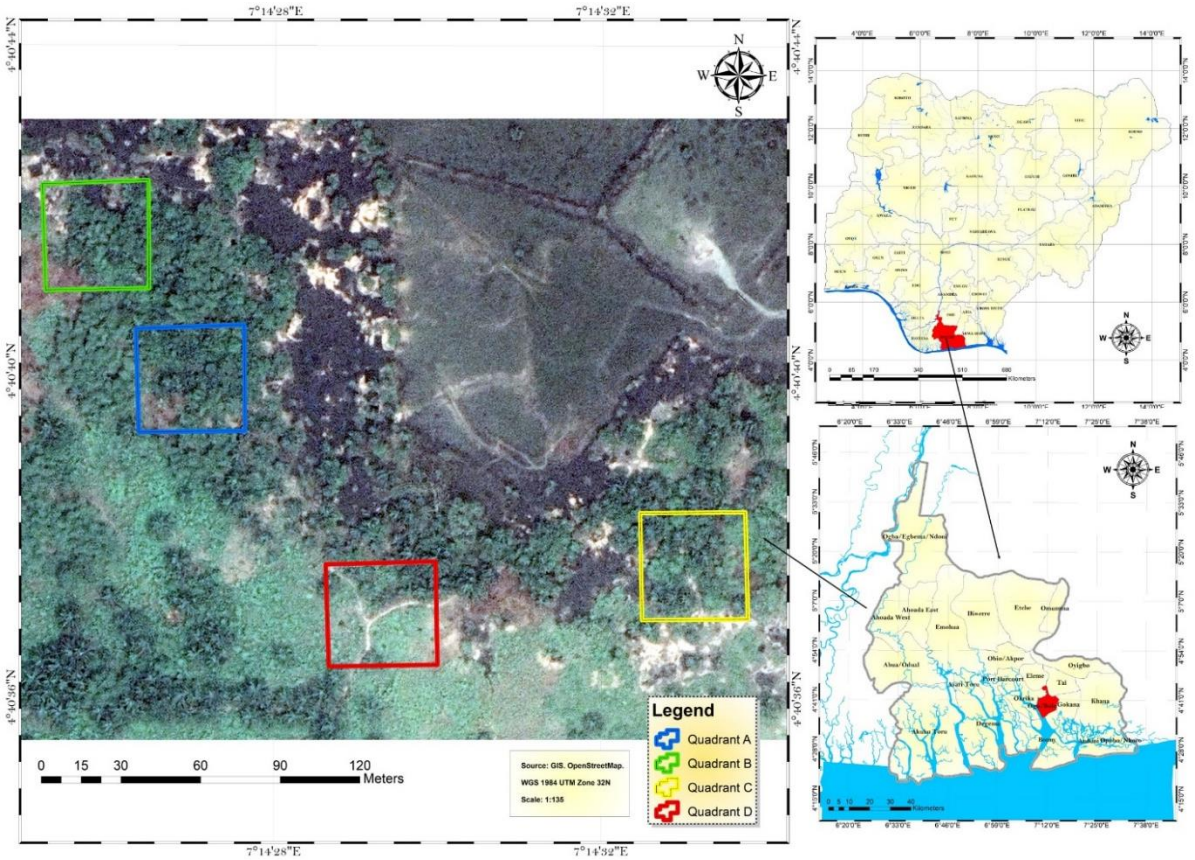
(1949) combining richness and evenness of species, subsequently complimented by Shannon–Wiener index (Shannon and Weaver, 1949) and Pielou's evenness measure (Pielou, 1966). In combination, these indices give subtle difference in insights into structure of community (Magurran, 2004; Krebs, 2014).

The study will provide insight into the impact of crude-oil pollution on diversity indices of vegetation in the K-Dere community in Gokana Local Government Area. The findings on diversity indices will be used to describe the vegetation-structure of the crude-oil-impacted area in the K-Dere community and to provide foundation for management and conservation operation in the future.

2. Materials and Methods

2.1 Study Site

The study area is within K-Dere community in Gokana Local Government Area of River State, Nigeria with **latitude (left edge, top to bottom):** 4°40'44"N, 4°40'40"N, 4°40'36"N and the **longitude (top and bottom edges):** 7°14'28"E and 7°14'32"E. The study area is characterized by two seasons, dry and rainy seasons. The dry season is from November to March while the rainy season is from April to October. The rainy season has a mean annual rainfall of 2400 mm, monthly mean temperature is 29^0 C, and dry season has a monthly mean temperature of 31^0 C. The area is in the belt of rainforest in the equatorial region's climate, attributed with heavy rainfall, high relative humidity, and high temperature.



Map of the Study Site

2.2 Vegetation Assessment

The assessment of vegetation was carried out using simple random sampling. A one-time four quadrat each measuring 40 m x 40 m (1600 square metre) represent the sample area from which plant species composition of the vegetation at the study site was sampled. Long measuring tape was used to map out the four corners of each single sample area (quadrat) of which each was 40 m and global positioning

system coordinate of each corner was recorded, used to generate geographic information system of each sampled area and a map showing the location of the four sampled area was created. Every single sampled area represent a plot, plot 1, 2 and 3 are sampled area containing plant community growing in crude oil polluted soil while the control (plot 4) is a sampled area containing plant community growing on soil uncontaminated with crude oil is at sufficient distance within the same habitat.

2.3 Diversity Indices formula

The following indices were computed for each plot:

Taxa (S): It gives the overall count of distinct species that occur in the sample

Dominance Index (D): $D = \Sigma(p_i)^2$, where p_i is the proportional abundance of species i.

Simpson's Diversity Index (1−D): Where D = sum $(Pi)^2$

Shannon–Weaver Index (H'): $H' = -\Sigma[p_i \ln(p_i)]$.

Evenness (e^H/S): Ratio of observed to maximum possible diversity.

3. Result

3.1 Species Recorded at the Study Site

A total of 41 plants species distributed across 21 families were recorded in the four plots studied with poaceae, fabaeceae and asteraceae being the dominant families.

Table 1: Species composition of the sampled vegetation

	Scientific Name	Common Name	Family	Plot 1	Plot 2	Plot3	Control (plot 4)
1	*Panicum maximum*	Guinea grass	Poaceae	40	43	130	281
2	*Pueraria sp.*	Tropical kudzu	Fabaceae	53	90	20	115
3	*Ageratum conyzoides*	Goat weed	Asteraceae	320	151	70	212
4	*Ageratum houstonianum*	Floss flower	Asteraceae	143	126	33	56
5	*Mikania sp.*		Asteraceae	35	150	50	75
6	*Cyperus rotundus*	Nut grass	Cyperaceae	23	22	30	68
7	*Aspilia africana*	Wild sunflower	Asteraceae	34	29	33	170
8	*Alchornea cordifolia*	Christmas bush	Euphorbiaceae	110	65	33	202
9	*Resentia sp.*		Trichocomaceae	35	32	65	71
10	*Mimosa pudica*	Sensitive plant	Fabaceae	70	65	33	59
11	*Elaeis guineensis*	Palm tree	Arecaceae	12	33	41	61
12	*Eleusine indica*	Goose grass	Poaceae	30	71	58	140
13	*Axonopus compressus*	Carpet grass	Poaceae	35	105	43	109
14	*Emilia sonchifolia*	Tassel flower	Asteraceae	130	0	0	95
15	*Andropogon gayanus*	Gamba grass	Poaceae	0	0	0	111
16	*Combretum sp.*	Bush willow	Combretaceae	72	82	54	0
17	*Senna alata*	Candle bush	Fabaceae	40	41	21	66
18	*Sida cordifolia*	Wire weed	Malvaceae	12	15	78	63
19	*Cyanthillium cinerem*	Little ironweed	Asteraceae	35	13	33	70
20	*Ipomoea aquatic*	Water chestnut	Convolvulaceae	18	20	42	131
21	*Striga gesnerioides*	Witch weed	Orobanchaceae	0	54	28	70
22	*Boerhavia diffusa*	Hog weed	Nyctaginaceae	111	80	120	45
23	*Senna sp*		Fabaceae	76	61	92	52
24	*Bambusa vulgaris*	Bamboo	Poaceae	205	58	31	40
25	*Calopogonium sp*		Fabaceae	0	0	31	49
26	*Acacia sp*		Fabaceae	112	64	51	45
27	*Cyathula prostrata*	Pasture weed	Amaranthaceae	21	40	90	40
28	*Diplazium sp.*		Athyriaceae	39	73	55	110
29	*Psidium sp.*	Guava	Myrtaceae	24	33	23	23

30	*Ficus sp.*	Fig tree	Moraceae	85	34	63	243
31	*Isoberlinia doka*	Doka ironwood	Fabaceae	50	23	32	161
32	*Manniophyton fulvum*	Gasso	Euphorbiaceae	90	60	37	120
33	*Cochlospermum planchonii*	False cotton	Bixaceae	181	35	85	48
34	*Newbouldia sp*	Boundary tree	Bignoniaceae	13	23	24	45
35	*Scoparia dulcis*	Goat weed	Plantaginaceae	210	44	40	44
36	*Mucuna pruriens*	Velvet bean	Fabaceae	210	110	33	38
37	*Paspalum scrobiculatum*	Crown grass	Poaceae	110	70	30	57
38	*Trema orientale*	Charcoal tree	Cannabaceae	34	153	43	91
39	*Albizia zygia*	West African albizia	Fabaceae	60	43	92	41
40	*Biophytum sp.*	Little tree	Oxalidaceae	60	51	32	63
41	*Elytrophorus spicatus*	Spike grass	Poaceae	200	21	52	40

3.2 Diversity Indices

Diversity indices for all four sites are summarised in Table 2. The table below presents the computed diversity indices—Taxa richness (S), Dominance (D), Simpson's Diversity (1 – D), Shannon–Wiener index (H), and Evenness (e^H/S)—for the four experimental plots.

Table 2: Diversity indices of the sampled vegetation

	Plot 1	Plot 2	Plot 3	Control
Taxa_S	38	38	39	40
Dominance_D	0.04577	0.03679	0.03283	0.03597
Simpson_1-D	0.9542	0.9632	0.9672	0.964
Shannon-Weaver_H	3.316	3.455	3.54	3.502
Evenness_e^H/S	0.7248	0.8329	0.8836	0.8298

The total number of taxa ranged from 38 in Plot 1 and Plot 2 to 40 in the control plot, indicating a relatively similar level of species richness across all sites. Species dominance (D) values were generally low, varying between 0.03283 (plot 3) and 0.04577 (plot 1).

Simpson's diversity index (1 – D) followed an opposite trend to dominance, ranging from 0.9542 (Plot 1) to 0.9672 (Plot 3). The control site also exhibited a relatively high Simpson's index (0.964), indicating high vdiversity and even species representation. The Shannon–Weaer diversity index (H) increased progressively from 3.316 in Plot 1 to 3.54 in Plot 3, with the control site (3.502) showing comparably high diversity.

Discussion

The results of the species diversity indices indicate that the studied plots and the control site possess a relatively high and comparable level of plant diversity. The total number of taxa ranged from 38 to 40 species, reflecting a stable and well-structured vegetation community. High species richness is often associated with habitat heterogeneity and favorable ecological conditions that support coexistence among multiple species (Magurran, 2013). The control site recorded the highest number of species (40), suggesting minimal disturbance and possibly more favorable microhabitat conditions compared to the experimental plots. Species dominance (D) values were low across all plots (0.03283–0.04577), implying that no single species monopolized the available resources. Low dominance values generally indicate a balanced community structure where several species share ecological space equitably (Pielou, 1966; Magurran, 2004). The lowest dominance in Plot 3 (0.03283) further confirms a more

even species distribution and less competitive exclusion compared to Plot 1, which showed the highest dominance (0.04577). The Simpson's Diversity Index (1–D) values (0.9542–0.9672) corroborate this pattern, revealing high species diversity across all sites. According to Simpson (1949), values approaching 1.0 reflect high diversity and reduced dominance. Thus, the higher Simpson's index observed in Plot 3 (0.9672) and the control (0.964) demonstrates a more equitable distribution of species abundance and better ecological stability. This trend agrees with findings by Odum and Barrett (2005), who noted that diverse plant communities tend to resist environmental fluctuations better and recover faster from disturbances. Similarly, the Shannon–Weaver Index (H), value (3.316 to 3.54), indicates that the vegetation is diverse and heterogeneous. Shannon index values greater than 3.0 are typically considered characteristic of highly diverse ecosystems (Krebs, 2014; Magurran, 2013). The highest Shannon diversity in Plot 3 (H = 3.54) suggests a well-developed vegetation structure and greater species complementarity, possibly due to less anthropogenic influence or more stable edaphic conditions. The control site also exhibited comparably high diversity (H = 3.502), reflecting a balanced and undisturbed environment that supports a variety of life forms. The Evenness values (0.7248–0.8836) further demonstrate uniform distribution of individuals among species. According to Pielou (1975), evenness values above 0.7 indicate that most species are equally represented in terms of abundance.

The highest evenness in Plot 3 (0.8836) signifies greater ecological equilibrium and reduced interspecific competition. High evenness and diversity values are often indicators of ecosystem stability and resilience (Tilman, 1999; Chiarucci et al., 2011). Overall, the observed pattern low dominance, high Shannon and Simpson indices, and high evenness suggests that the vegetation across the sites is mature, structurally stable, and ecologically balanced. Plot 3 and the control site displayed the most diverse and evenly distributed plant communities, likely due to reduced stress factors or better soil and microclimatic conditions. These findings align with earlier studies that link high biodiversity to greater ecosystem productivity and resilience (Loreau et al., 2001; Cardinale et al., 2012).

Conclusion

The taxa suggest that the species richness in both contaminated and uncontaminated (control) areas are within a narrow margin, indicating a relatively similar level of species richness across all sites. The highest number of species in control plot suggests low disturbance and more favourable environmental. Species dominance has several low values suggesting that no single species overwhelmingly dominated the communities. Plot 3 has the lowest dominance while the highest was in plot 1 implying greater species dominance in the former followed by the control. Simpson's diversity index (1-D) values indicate high diversity and even species representation across all sites with the highest recorded in plot 3 followed by control. The Shannon-Weaver index indicates a highly divers and heterogenous ecosystem. Having a value greater than 3.0 suggests an ecosystem that is highly diverse with plots being more developed vegetation structure and greater species complementarity followed by control. Since they are all above 0.7, the Evenness indicates uniform distribution of individuals among species.

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