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Exploring the Richness Below: A Comprehensive Introduction to Evaluating Soil Seed Bank Composition and Diversity

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Abstract

The objective of this research was to evaluate the soil seed bank, floristic composition and diversity of soil from solid waste dumpsite within Choba, Alakahia and Rumuosi in Akpor, Rivers State, Nigeria. Soil samples were collected randomly within the selected locations at different depths (0-5cm, 5-10cm, and 10-15cm) using a soil auger. The seedling emergence method was used for the soil seed bank analysis. The Shannon/ Weiner diversity index was used for species diversity. Result revealed total of 49 individual of 15 species in site1; 47 individual of 13 species in site 2 and 43 individual of 14 species in site 3. The highest in the number of individuals was recorded in control site 2 (528). The Asteraceae family dominated the soil seed bank at site 1; Spermacoceae site 2 and Poaceae site 3. The number of seedlings emergent for 0-5cm depth for Ozuoba; choba; and Alakahia were 20±0.02; 21±0.001; and 20±0.2. Furthermore, Ozuoba samples site revealed highest seedling emergent number at 5-10cm depth while 10-15cm was recorded for Choba. A thriving and diverse plant community was predominate in the control sites which customarily showed the severe impact of spent oil pollution on vegetation.

Keywords: Soil seed bank, Plant species density, Diversity, Composition, Solid wastes, Evenness

Introduction

In the realm of ecology and conservation biology, the concept of soil seed banks stands as a fundamental yet often overlooked aspect of ecosystem dynamics. Beneath the surface of terrestrial ecosystems lies a hidden reservoir of life waiting to sprout and flourish – the soil seed bank. Within this soil seedbank lies the potential key to understanding the composition and diversity of plant communities, essential for unraveling the intricacies of ecosystem dynamics and biodiversity conservation (Obianefo, *et al*. 2017). Soil seed banks represent a reservoir of plant propagules that lie dormant within the soil, capable of germinating under suitable conditions to regenerate vegetation (Mason et al 2007). This reservoir not only plays a crucial role in maintaining biodiversity but also influences ecosystem resilience, succession patterns, and response to environmental changes. The study of soil seed banks has garnered increasing attention due to its implications for ecological restoration, land management, and understanding plant community dynamics (Venable and Lawlor 1980; Obianefo *et al* 2017). Evaluating soil seed banks involves a multifaceted approach encompassing ecological, physiological, and methodological aspects. This comprehensive introduction aims to delve into the fundamental principles, significance, assessment methods, and ecological implications of soil seed banks. The soil seed bank is significantly affected by human activities, which profoundly influence its composition and diversity. Anthropogenic pressures such as land-use changes and pollution alter the ecological dynamics of terrestrial ecosystems. This investigation seeks to elucidate the complex impacts of these human activities on soil seed bank composition and diversity, utilizing empirical evidence and scholarly insights to understand the mechanisms driving these transformations and their implications for biodiversity conservation and ecosystem management. Urbanization, agriculture, and deforestation fragment natural habitats, leading to the loss of native vegetation and alterations in soil characteristics. These changes in land use disrupt seed dispersal mechanisms, reduce seed availability, hinder seed emergence, and subsequently create opportunities for invasive species to establish themselves (D'Antonio, and Vitousek 1992; Obianefo, *et al*. 2017). Anthropogenic activities such as the introduction of heavy metals, pesticides, and nutrient runoff contaminate soils, potentially altering their physicochemical properties and impacting seed bank dynamics. Facilitate the introduction and spread of invasive plant species, which often possess high seed production, wide dispersal capabilities, and competitive advantages over native flora. Invasive species alter soil seed bank composition by outcompeting native seeds for resources, inhibiting their germination and establishment, and forming persistent seed banks dominated by non-native species. The displacement of native species by invasive plants in soil seed banks disrupts ecosystem functioning, reduces biodiversity, and poses challenges for ecological restoration and conservation efforts (D'Antonio, and Vitousek 1992). Pollution induced stressors affect seed viability, dormancy, and germination, leading to reduced seedling recruitment and shifts in soil seed bank composition towards pollution-tolerant or resistant species. Soil degradation resulting from pollution compromises ecosystem resilience, diminishes plant diversity, and hampers the capacity of soil seed banks to support ecosystem recovery and regeneration (Huang, *et al* 2010). The interaction between anthropogenic climate change and other stressors further compounds the challenges faced by soil seed banks, reducing their capacity to sustain plant communities and ecosystem functions (Walck et al 2011). However, evaluating soil seed bank composition and diversity unveils a wealth of insights into the hidden biodiversity beneath our feet, providing a window into the ecological processes shaping plant community dynamics and ecosystem resilience. By integrating methodologies, ecological theory, and empirical evidence from a diverse array of references, this introduction lays the groundwork for further exploration of soil seed bank diversity assessment, guiding future research endeavors and conservation initiatives aimed at preserving the richness of terrestrial ecosystems.

Significance of the study: The significance of evaluating soil seed bank composition and diversity lies in its implications for ecosystem restoration, conservation, and management. By studying the types and abundance of seeds present in the soil seed bank, researchers and land managers can gain insights into historical land use patterns, predict future vegetation dynamics, and develop effective strategies for habitat restoration and invasive species control.

Materials and Methods

Soil collection: Soil samples were collected from nine (6) different locations within three (3) communities (Ozuoba, Alakahia and Choba) in Obio/Akpor Local Government Area; three (3) spent engine oil sites and three (3) control sites. Geographical locations were recorded using a GPS device and is listed below

Table1: Study Sites with GPS point and collection distance

S/N	Location/Sites	Latitude	Longitude
1	Ozuoba spent oil site 1	4.3054	9.88526
2	Control site	4.4875	6.9264
3	Alakahia spent oil site 2	4.895	6.9133
4	Control site	4.395	6.9153
5	Choba spent oil site 3	4.894	6.9111
6	Control site	4.894	6.9111

Sampling Procedure / Collection: Soil samples were collected randomly within the selected locations at different depths (0-5cm, 5-10cm, and 10-15cm) using a soil auger. This method ensures representative sampling from various depths, which is crucial for understanding soil characteristics and potential contamination profiles. The collected soil samples were carefully labeled and transported to the Rivers State University Botanical Garden. Proper labeling is essential for accurate tracking and analysis of the samples.

Preparation and Analysis: At the laboratory, the soil samples underwent physico-chemical analysis to determine their initial nutrient concentrations. This step provides baseline data on soil composition and nutrient levels, which is important for evaluating changes due to contamination.

Seedling Emergence Test: The soil samples were subjected to a seedling emergence test to assess seed viability, density, and species composition. This involved placing 100g of soil samples in perforated plates with filter paper at the bottom to prevent soil and water loss. The plates were watered daily and monitored for seedling emergence over a period of twelve weeks. As seedlings emerged, they were identified, counted, and removed. This process was carried out weekly, starting from the first week of plating. Seedlings that couldn't be immediately identified were transplanted until they could be identified.

Analysis of Results: The data collected from the seedling emergence test can provide insights into the impact of soil contamination on seed germination and seedling establishment. By comparing results between contaminated and non-contaminated sites, as well as different depths, researchers can assess the extent of contamination and its effects on plant biodiversity and ecosystem health. Overall, this methodology allows for a thorough assessment of soil quality, seed viability, and species composition in the study area, providing valuable information for environmental management and remediation efforts.

Data collected for seedling emergence were subjected to two-way analysis of variance (ANOVA) to ascertain the significant difference within factors. Also, multiple comparison using least significant difference (LSD) was applied to determine significant difference between paired factors using SAS 9.2 version. This was done to compare seedling emergence from the seed banks of the contaminated and non-contaminated sites and number of emergent seedlings from the various depths.

Results

The study of species composition and seedling emergence across different sites impacted by spent oil pollution, as well as their respective control sites, reveals significant variations in both the number of seedlings and the diversity of species.

The findings, as summarized in Table 1, showed the presence of dominant plant species at the control Sites (Ozuoba, Alakahia and Choba). Ozuoba control site is dominated by *Eleusine indica* having 75 individuals, followed by *Alchornea cordifolia* Müll.Arg with 100 individuals, and *Phyllanthus*sp with 41 individuals. Alakahia control site (C2) is seen as the most diverse speciation having species such, *Oldenlandia corymbosa* L (58), *Vernonia cinera*(56), *Alternanthera brasiliana* (L. Kuntze) (80), and *Cyperus difformis* (98) showing high counts. Choba control site (C3) was characterized by sedges (65), *Mimosa pudica* L. (8), and *Aspilia africana* (Pers.) (13), but overall lower species numbers compared to C1 and C2. The impact of spent oil contamination was pronounce in the seedling emergence at these sites was significantly lower, with totals of 49, 47, and 43 seedlings across the three sites respectively, emphasizing the adverse impact of human interference. Species richness and dominance was reported. In Ozuoba control sample site (C1), Fifteen families were identified, with *Aspilia africana* being the most dominant species. While in Alakahia control sample site thirteen families were observed, with *Oldenlandia corymbosa* (spermacoceae family) as the most dominant species. However, Choba control site, showed similar response in family composition, but dominated by *Eleusine indica* (Poaceae family).

The seedling emergence total in control sites (Ozuoba, Alakahia, Choba) were 464, 528, and 299 respectively indicating healthy and conducive conditions for germination and growth. The highest seedling emergence of 528 was recorded at Alakahia control site. The Alakahia control sites with the highest number of individuals, suggesting particularly favorable conditions for plant growth. The reference sites (control) exhibited significantly higher species richness and seedling emergence compared to the spent oil-contaminated sites. This underscores the detrimental impact of oil pollution on biodiversity and plant health. Each site had a distinct dominant species, which may reflect the specific ecological conditions and resilience of these species to local environmental factors.

Table 1: Summary of total number of Emergent seedlings recorded across the sample locations

Family	Species	Site 1	Site 2	Sites3	C1	C2	C3
Spermacoceae	*Oldenlandia corymbosa L*	6	8	4	45	53	30
Poaceae	*Eleusine indica L*	0	3	9	75	66	43
Cyperaceae	*Sedges*	1	6	0	27	10	65
Asteraceae	*Ageratum conyzoides L..*	4	0	6	0	0	1
Asteraceae	*Vernonia cinera Delile*	7	4	1	0	56	30
Amaranthaceae	*Alternanthera brasiliana(L. Kuntze)*	0	1	4	22	80	27
Poaceae	*Panicum maximum Jacq.*	2	4	0	33	5	10
Fabaceae	*Mimosa pudica L.*	0	0	3	3	0	8
Malvaceae	*Sida acuta Burm.f.*	2	6	5	15	7	4
Asteraceae	*Aspilia africana(Pers.) C.D. Adams*	8	7	4	11	7	13
Euphorbiaceae	*Alchornea cordifolia Müll.Arg.*	0	1	0	100	98	42
Phyllanthaceae	*Phyllanthus sp*	7	4	3	41	0	0
Cyperaceae	*Cyperus iria*	0	0	1	0	8	2
Cyperaceae	*Cyperus difformis*	2	0	1	55	98	6
Amaranthaceae	*Amaranthus sp*	1	0	0	4	7	2
commelinaceae	*Commelina sp*	0	1	0	0	0	2
Asteraceae	*Chromoleana sp*	1	0	0	0	0	0
Onagraceae	*Ludwigia sp*	2	1	0	22	10	2
Poaceae	*Setaria sp*	2	0	0	2	0	1
Asteraceae	*Aspilia sp*	1	0	1	0	0	0
Poaceae	*Echinochloa colona* Link	3	1	0	9	0	2
Solanaceae	*Physalis sp*	0	0	1	0	23	9
Number of Individual		49	47	43	464	528	299
Number of species		15	13	14	14	14	19

Emergent of seedling with depth

Comparatively, the difference in the number of emergent seedling from various sample at 0-5cm depth showed that seedling emergent at Ozuoba (site 1) was 20 ±0.02 and 200 ± 2.05seedling by count for spent oil polluted and control site respectively. This trend was also found at Alakahia (site 2) and Choba (site 3) which is seen as 21 ± 0.001; 342 ± 5.6; 20±0.01, 150 ± 8.3. Alakahia spent oil site had the highest species occurrence at 0 – 5cm depth, this also gained reflection with control across treatment. At depth 0-5 cm seedling emergence is generally higher in control sites compared to polluted sites across all locations. Alakahia's control site, in particular, shows a remarkably high seedling emergence, indicating very favorable conditions for germination.

The difference in the number of emergent seedling at depth 5- 10cm showed that Ozuoba (site 1) sample area had the highest seedling emergent both in control and spent oil contaminated soil as 135 ± 12.01 and 17±0.03 respectively. At 5-10 cm Depth Ozuoba’s control site continues to show robust seedling emergence, indicating consistent soil fertility and suitable conditions across different depths. At depth 10- 15cm, it was reported that Choba (site 3) spent oil area showed highest emergent seedling across treatment while Ozuoba (site 1), showed highest seedling emergent in control site as 129 ± 15 at 10-15 cm. Choba's polluted site shows resilience with the highest seedling emergence among polluted sites at this depth, suggesting deeper soil layers may offer some protection against pollution effects.

Species Occurrence and Biodiversity:

Alakahia’s spent oil site showing the highest species occurrence at 0-5 cm depth suggests that despite pollution, a variety of species can still germinate and emerge, although in lower numbers compared to control sites. Ozuoba study site shows consistently high seedling emergence in control sites across all depths, with some resilience in polluted conditions at 5-10 cm depth. Alakahia site also exhibits the highest seedling emergence and species occurrence at 0-5 cm depth in both control and polluted conditions, indicating strong site fertility. While Choba demonstrates significant resilience at deeper soil layers (10-15 cm) in polluted conditions, suggesting potential for remediation at deeper depths. The data indicates a clear negative impact of spent oil pollution on seedling emergence across all sites and depths. Control sites show significantly higher seedling emergence, highlighting the detrimental effects of pollution. However, certain sites and depths, such as Alakahia at 0-5 cm and Choba at 10-15 cm, show notable resilience, suggesting areas for focused remediation efforts. This comprehensive understanding aids in developing targeted strategies for soil restoration and promoting biodiversity in polluted areas.

Table 2: Summary of Species Diversity for the Study Sites

	Site 1	Site 2	Site 3	C1	C2	C3
Taxa_S	15	13	13	14	14	19
Individuals	49	47	43	464	528	299
Dominance_D	0.10	0.11	0.11	0.11	0.13	0.12
Simpson_1-D	0.89	0.88	0.88	0.88	0.86	0.87
Shannon_H	2.45	2.33	2.32	2.34	2.20	2.36
Evenness_e^H/S	0.77	0.78	0.78	0.68	0.64	0.55
Menhinick	2.14	1.89	1.92	0.68	0.60	1.09
Margalef	3.59	3.11	3.19	2.28	2.64	3.15

Table 3: Difference in the number of emergent seedlings for the various sample locations at 0-5 cm depth

Treatment	Ozuoba	Alakahia	Choba	LSD
Spent Oil	20±0.02^{a}	21±0.002^{ab}	20±0.2^{a}	1.04
Control	200±2.9^{b}	324±3.0^{a}	150±4.6^{bc}	13.12

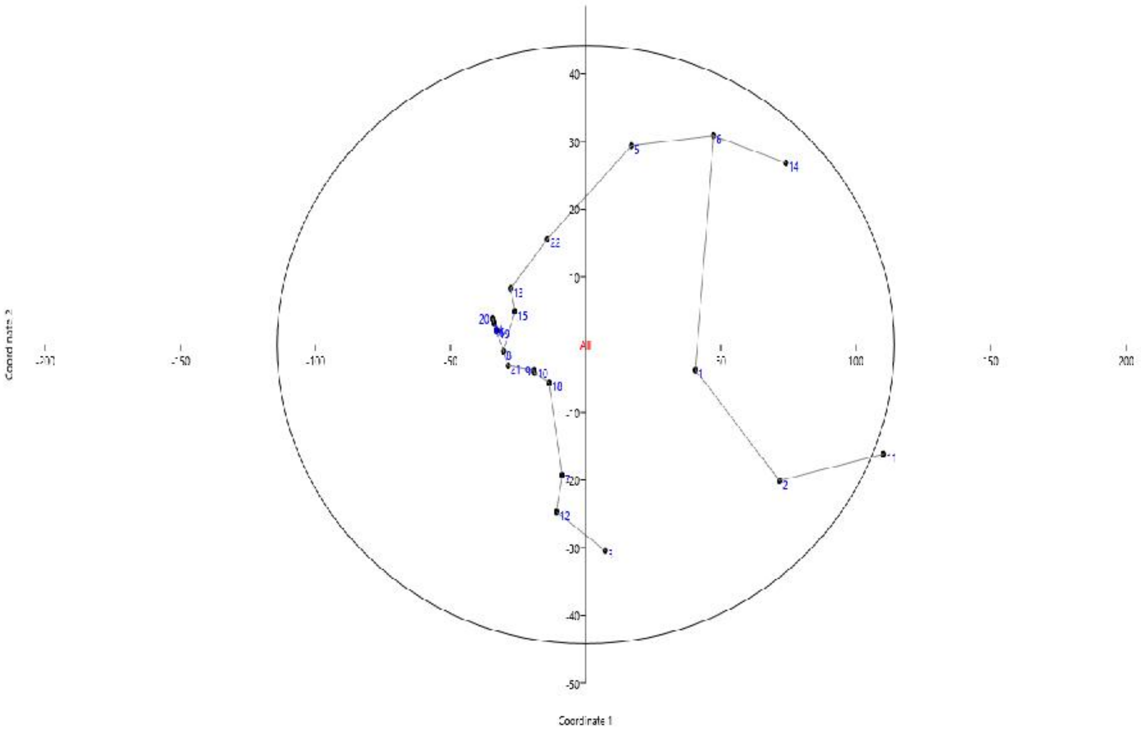
Table 4: Difference in the number of emerhent seedlings for the various sample locations at 5-10cm depth

Treatment	Ozuoba	Alakahia	Choba	LSD
Spent Oil	17±0.1^{a}	15±0.2^{a}	13±0.002b	3.04
Control	135±22^{a}	100±14^{b}	100±11^{b}	20.32

Table 5: Difference in the number of emerhent seedlings for the various sample locations at 10-15 cm depth

Treatment	Ozuoba	Alakahia	Choba	LSD
Spent Oil	10±0.002^{a}	10±0.002^{a}	11±0.2^{a}	1.04
Control	129±11^{a}	54±2.02^{b}	49±3.0^{b}	14.2

Means ± standard error with different alphabets are significant at 5% probability level.



Discussion

Species diversity studies in and around anthropogenic impacted area is important to determine the mechanisms responsible for high diversity, species richness and species assemblages. *Eleusine indica*, commonly known as goose-grass, is a dominant species often found in disturbed areas such as agricultural fields, roadsides, and urban environments. Its prevalence at control sites in Ozuoba, Alakahia, and Choba highlights its adaptability and competitive nature. *Eleusine indica* thrives in various environmental conditions, which makes it a common species in many tropical and subtropical regions. It can grow in poor soil conditions and is tolerant of drought and heavy trampling (Chauhan, 2013). This adaptability likely contributes to its dominance in the control sites at Ozuoba, Alakahia, and Choba. This plant species is known for its robust competitive ability, which allows it to outcompete other species for resources such as light, water, and nutrients. This trait is particularly important in disturbed sites where competition can be fierce due to the availability of resources and space (Iqbal, *et al.* 2019).The dominance recorded in the control study site is understandable since *Eleusine indica* produces allelopathic chemicals that inhibit the growth of other plant species around it. This allelopathy provides it with a competitive edge, further cementing its dominance in various habitats (Inderjit, & Duke, 2003). The dominance of *Eleusine indica* at the control sites can also lead to reduced biodiversity by outcompeting native species, it can create monocultures that diminish habitat diversity, which in turn affects the entire ecosystem, including soil health and local fauna (Lal, 2001). This plant species helps prevent soil erosion due to its dense root system, its dominance can lead to soil degradation over time. The lack of plant diversity can reduce soil organic matter and affect the soil structure negatively, impacting long-term land productivity (Chauhan, 2013). The dominate nature of *Eleusine indica* in areas with frequent human activity or disturbances, which aligns with observations from the control sites in Ozuoba, Alakahia, and Choba corroborated with the report of Iqbal et al. (2019) indicated that *Eleusine indica* was prevalent in disturbed sites due to its rapid growth rate and high seed production. The difference in species composition between Alakahia and Choba control sites can be attributed to various ecological factors such as soil type, moisture levels, human activity, and microclimatic conditions. Alakahia's control soil, was characterized by diverse species, indicates a more heterogeneous environment, whereas Choba's control sites dominated by sedges suggest specific environmental conditions favoring these plants. The diverse species composition in Alakahia's control soil suggests a range of microhabitats and ecological niches. Such diversity typically indicates variations in soil properties, moisture levels, and light availability, supporting a wider range of plant species. High species diversity in Alakahia contributes to ecosystem resilience, stability, and productivity. Diverse plant communities can improve soil structure, enhance nutrient cycling, and provide habitats for various fauna, thereby supporting overall ecosystem health. The presence of diverse species may also reflect varying levels of human disturbance and natural succession stages.

Less disturbed areas or those in intermediate stages of succession often show higher species diversity compared to highly disturbed or early successional stages. Mitsch, and Gosselink, (2015) reported increase in species richness and distribution patter in unperturbed environment.

The dominance of sedges in Choba could be attributed to the condition of the soil. The plant habit (sedges) are typically found in moist or waterlogged environments. These plants are well adapted to such conditions, with specialized root systems that can tolerate anaerobic soil environments. Sedges thrive in soils with specific characteristics, such as high clay content or poor drainage, which might be prevalent in Choba. These soils can retain water longer, creating an ideal habitat for sedges but less suitable for a wider range of plant species. This findings corroborated with Cardinale *et al*. (2012) who reported on the competitive nature of sedges and their ability to thrive in wet conditions can lead to their dominance in such environments. It was also reported that dominance often results in lower species diversity, as few other species can compete effectively in these niches. While Alakahia's diverse plant community enhances ecosystem services like pollination, soil fertility, and habitat provision, Choba's sedge-dominated environment might focus on services like water filtration, soil stabilization, and specific wildlife support adapted to wet conditions. Understanding these differences is crucial for land management and conservation strategies. Efforts in Alakahia might focus on preserving species diversity and preventing invasive species, while in Choba, maintaining hydrological conditions and protecting wetland habitats could be priorities. Recent studies have highlighted the importance of plant diversity in maintaining ecosystem functions and resilience. This results also agrees with Cardinale *et al.* (2012) found that biodiversity enhances ecosystem productivity and stability, underscoring the value of diverse plant communities like those in Alakahia. Equally, research by Mitsch and Gosselink (2015) on wetland ecosystems emphasizes the critical role of species like sedges in waterlogged environments, highlighting their ecological importance in areas like Choba.

This area is known for its industrial activities, particularly oil-related operations, has been significantly impacted by spent oil contamination. Research has shown that seedling emergence in Choba is notably lower compared to less polluted areas. Spent oil contamination, which refers to the environmental pollution caused by used engine or industrial oils, can have a pronounced negative impact on seedling emergence. This effect is particularly notable in areas like Choba, where industrial activities are prevalent. This contamination predominate the study area affects the physical and chemical properties of the soil, leading to a reduction in seedling emergence. The presence of spent oil in the soil creates a hydrophobic layer that impedes water infiltration and retention. This limits the availability of water necessary for seed germination and early growth stages. Additionally, the oil may contain heavy metals and other toxic substances that can inhibit seedling development by interfering with nutrient uptake and causing phytotoxic effects. Njoku *et al*. (2009) found that spent engine oil significantly reduces seed germination and growth in some plants due to its toxic effects on the soil environment. Equally, Ujowundu *et al.* (2011) reported that soil contaminated with spent oil in the Niger Delta region, including Choba, exhibited reduced seedling emergence and growth, highlighting the severe environmental impact of oil pollution in this area. Osuji and Onojake (2004) emphasized that spent oil contamination leads to poor soil structure and aeration, further exacerbating the difficulties in seedling establishment and growth. The variations in dominant species and the number of identified plant families among these sites highlight the influence of environmental conditions on plant community structures. Dominant species in disturbed or contaminated areas are often those that can withstand adverse conditions, reflecting the ecological health of these sites. *Aspilia africana*, commonly known as the wild sunflower, is noted for its resilience and ability to thrive in various soil types, including those with moderate disturbances. Its dominance in Ozuoba indicates a relatively stable and less polluted environment, conducive to the growth of diverse plant families. *Aspilia africana* is also known for its medicinal properties and ecological benefits, such as soil stabilization and support for pollinators. *Oldenlandia corymbosa* also known as diamond flower, is a small, herbaceous plant common in tropical regions. Its presence as the dominant species suggests that Alakahia has a slightly disturbed habitat, but still supports a variety of plant families. This species is known for its ability to grow in various soil conditions, indicating that while the site may not be heavily contaminated, it experiences some environmental stress that favors hardy, adaptable plants. *Eleusine indica* as a robust grass species are often found in disturbed soils. Its dominance in Choba suggests that the area is more disturbed compared to Ozuoba and Alakahia. This grass is highly adaptable and can tolerate poor soil conditions, which is indicative of environmental stress, possibly due to contamination or other anthropogenic activities. The presence of species like *Eleusine indica* and *Oldenlandia corymbosa* in Alakahia and Choba control sites suggests that these areas are under more significant environmental stress compared to Ozuoba. This stress could result from factors such as soil contamination, physical disturbance, or nutrient imbalances. The greater number of plant families in Ozuoba indicates higher biodiversity, which is often associated with healthier ecosystems. Higher biodiversity typically correlates with better ecosystem functioning, resilience, and stability. Areas with higher plant diversity, such as Ozuoba, are generally more resilient to environmental disturbances and can recover more quickly from contamination. This findings corroborate with Oladipo *et al*. (2004) who emphasized the importance of plant diversity in assessing soil health and ecosystem stability. Agbogidi *et al.* (2007) studied the impact of soil contamination on vegetation and found that areas with higher levels of pollutants tend to support fewer plant families and are dominated by species that can tolerate harsh conditions, similar to the findings in Choba and Alakahia.

Conclusion

The study emphasizes the severe impact of spent oil pollution on the emergence of seedlings and the diversity of plant species in affected sampled sites. In sites free from such contamination, referred to as control sites, a thriving and diverse plant community is observed. These control sites exhibit a high number of seedlings and a wide variety of species, indicating a healthy and self-sufficient ecosystem. Furthermore, sampled areas polluted with spent oil showed a marked decrease in both the number of seedlings that emerge and the richness of species present. This significant reduction highlights the detrimental impact of spent oil on plant life. The findings of the study underscore the critical need for remediation efforts to clean up these polluted environments. Such efforts are essential to restore the natural habitat, support the recovery of plant communities, and promote overall biodiversity. The study advocates for proactive measures to mitigate pollution and rehabilitate affected areas to ensure the sustainability and health of the ecosystem.

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