International Journal of Advanced Research in Botany
Volume 8, Issue 1, 2024, PP 1-13
ISSN 2455-4316 (Online)
https://doi.org/10.20431/2453-4316.0801001
www.arcjournals.org

Spatial and Depth-Related Variability of Soil Seed Banks in Relation to Land Use and Environmental Disturbance: A Case Study of Poaceae Dominance in Tropical Ecosystems

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Abstract

The research examined the soil seed bank dynamics in different land use ecosystem in Nnamdi Azikiwe University, Awka and Amansea. The study also went further to evaluate the seed bank richness and abundance at different soil depths to determine soil seed bank composition in abandoned farmland, Cattle grazed, watershed, and roadside ecosystems (environmental disturbance). Survey method was used to sample 600 sqm of land which was further divide into seven areas with reference to activities ranging from abandoned farmland, moderately grazed, heavily grazed, perennial watershed, annual watershed, roadside and footpath to carry out the study. Soil samples were collected at varying depths using a soil auger for germination analysis. Results from the study showed sprouts of species from the soil seed bank which has very significant ecological importance, playing diverse roles within ecosystems. Additionally, the result identified specific species that germinated in the different soil samples collected from the various locations. Species like C. dactylon, D. Sanguinalis, P. maxium, B. deflexa, M. alternifolius, and S. Pumila germinated in all the soil depths of the different sites. The present findings revealed that Setaria viridis was the most abundant species that germinated across the three-soil depth of abandoned farmland site while Digitaria sanguinalis was the most abundant across the three-soil depth of footpath site. For the heavily grazed site, Setaria viridis recorded highest abundance across the three soil depth while for the moderately grazed site, Digitaria sanguinalis was the most abundant sprout at the depth of 0-5cm, Cyperus rotundus was the most abundant at the soil depth of 6-10 cm and Edrastima uniflora was the most abundant at the depth of 11-15 cm. Roadside study site revealed that Capiscum annum was the most abundant at the depth of 0-5cm, Cynodon dactylon was the most abundant at the soil depth of 6-10 cm while Aristolochia serpentaria, Cyperus rotundus and Digitaria sanguinalis were the most abundant at the depth of 11-15 cm. Overall, the moderately grazed site recorded the highest seed bank density of 26 seeds per square meters while the roadside experimental site recorded the lowest seed bank density of 2 seeds per square meters. The analysis of variance indicates that soil depth significantly accounts for the variation in seed bank density, whereas sites do not.

Keywords: *Soil, Seed bank, Ecosystem, Watershed, Farmland, Grazed, Abundance, Plants*

1. Introduction

Soil seed banks on the other hand, are the dormant seeds that are present in the soil, waiting for the right conditions to germinate and grow into new plants. Soil seed banks consist of seeds from a variety of plant species that have fallen to the ground and either have not yet germinated or have germinated but have not yet emerged from the soil. Soil seed banks are important for the persistence and resilience of plant populations and communities, as they can help to ensure that plant species such as Poaceae are able to survive environmental disturbances such as fire, flooding, or drought. Soil seed banks can also help to maintain genetic diversity within plant populations, as seeds can remain dormant in the soil for many years before germinating. Despite their enormous ecological importance and substantial contributions to plant biodiversity, they are rarely investigated and frequently left out of floristic studies. This necessitates this study into investigating the composition, distribution, and seed bank composition of *Poaceae* species growing in the Nnamdi Azikiwe University, Awka.

Seed bank, often overlooked beneath the soil surface, holds the potential to shape the trajectory of ecosystems. Understanding the distribution of seeds at different soil depths provides critical information about the persistence of plant species, succession dynamics, and the restoration potential of disturbed areas. By analyzing studies from the past few years, we can unravel the complex relationship between seed bank richness, abundance, and soil depth.

Research endeavours have shed light on the richness of seed banks across various soil depths. Studies by [1] demonstrated that while shallow soil depths predominantly housed seeds of pioneer species, deeper layers exhibited a higher diversity of species, including those with longer dormancy periods [1]. This spatial variation in seed bank richness underscores the importance of considering multiple soil layers for effective restoration and conservation strategies. Investigations into seed bank abundance patterns within different soil strata have revealed intriguing dynamics. The uppermost soil layer contained the highest seed abundance, aligning with the accessibility of light and moisture for germination [2]. However, deeper soil layers retained a reservoir of dormant seeds, which could potentially contribute to vegetation recovery under changing environmental conditions.

Understanding the distribution of seeds across different soil depths has direct implications for ecological restoration efforts. Restoration practitioners must consider the stratification of seed banks when selecting appropriate plant species for re-establishment. Johnson and Martinez [3] emphasized that the presence of dormant seeds in deeper layers could influence the trajectory of post-restoration community assembly, potentially leading to the emergence of species not immediately apparent in aboveground vegetation.

The interplay between seed bank dynamics and succession processes is a focal point of recent research. Brown and Garcia [4] investigated how seed bank composition changed with soil depth during post-disturbance succession. They discovered that deeper soil layers exhibited a temporal sequence of species emergence, suggesting that these layers contribute to long-term community development [4]. These findings challenge the traditional view of seed banks as short-term reservoirs. Anthropogenic activities, such as agriculture and construction, can disturb soil layers and disrupt seed bank dynamics. Savadogo *et al.* [5] explored how seed banks respond to different levels of soil disturbance. They found that while shallow disturbances affected the upper seed bank layers, deeper disturbances influenced the dormant seed pool, potentially altering the trajectory of vegetation recovery [5, 6, 7]. The exploration of seed bank richness and abundance across different soil depths provides a nuanced understanding of plant community dynamics and ecosystem resilience. As we delve deeper into the hidden world beneath the soil surface, we uncover intricate interactions that influence succession, restoration, and adaptation to changing environments. By integrating this knowledge into land management strategies, we can foster more effective and sustainable approaches to conserving and restoring diverse ecosystems.

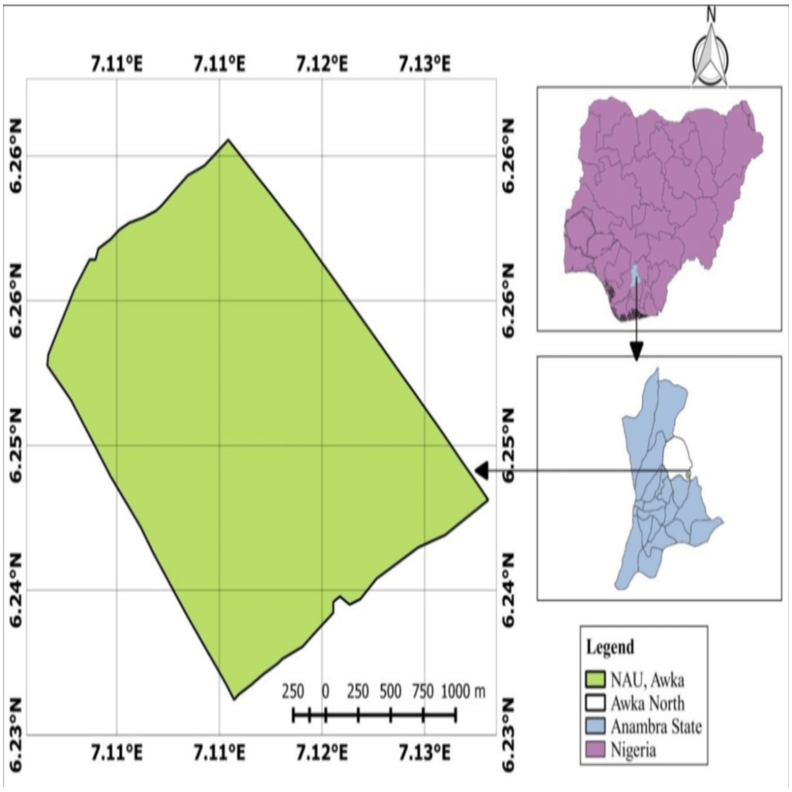
The research was focused on soil seed bank dynamics in different land use ecosystems at Nnamdi Azikiwe University Awka and Amansea. Understanding the seed bank dynamics of *Poaceae* species can guide restoration efforts, ensuring the maintenance of resilient and functioning ecosystems that benefit both people and nature. Environmental advocates and organizations dedicated to biodiversity conservation benefit from a comprehensive study on *Poaceae* species. Fellow researchers within the field of botany, ecology, and related disciplines will gain new insights from this study. The data on *Poaceae* species' seed bank dynamics and distribution will provide a foundation for further research endeavors. This knowledge can stimulate collaborative efforts, spark innovative research questions, and contribute to the advancement of scientific knowledge about these critical plant species.

2. MATERIALS AND METHODS

2.1. Description of the Study Areas

This study was carried out in the Nnamdi Azikiwe University Awka campus and Amasea areas of Awka South East Nigeria. Awka is located between the coordinates Latitude 6.24678° or 6° 14' 48'' North and Longitude 7.11553° or 7° 6' 56'' East (Richards, 2015), elevation 54 metres (177 feet). Total area of $4200m^2$ will be mapped out for the study, each of the mapped out area measuring $600m^2$ i.e 30m x $20m^2$ each using pegs and ropes for demarcations to identify its borders. Each site's precise location was located using a handheld GPS (Global Positioning System) tool Garmin eTrex (latitude, longitude, and altitude).

Awka is in the tropical rainforest zone of Nigeria and experiences two distinct seasons brought about by the predominant winds that rule the area. The Southwestern monsoon winds from the Atlantic Ocean and the Northeastern dry wind across the Sahara desert. The monsoon winds from the Atlantic creates seven months of heavy tropical rains which occurs between April and October and followed by five months of dryness November to March [8]. The harmattan is particularly dry, filled with dusty wind which enters Nigeria in late December or in early part of January and is characterized by gray haze limiting visibility and blocking the sun's rays. The temperature in Awka is generally 32^0C to 34^0C between January and April, 27^0C to 30^0C between June and December, with these last few months of dry season marked with intense heat.



2.2. Site Selection

Study sites where selected to represent the four main study areas and where further split to obtain seven study areas to effectively carry out the study objectives. The seven different terrestrial ecosystems, which served as the study areas or experimental sites, include:

1. Abandoned Farmland located opposite unizik fire station complex (Site 1)
2. Moderate Grazed Land, located at along Unizik Church complex Gate (Site 2)
3. Heavily Grazed Land, located at Garki Area of Amansea (Site 3)
4. Perennial Watershed, located near Unizik Botany forest (Site 4)
5. Annual Watershed, located near Agric faculty (Site 5)
6. Regularly Used Roadside, located at Science village (Site 6)
7. Footpath located near Botany laboratory (Site 7)

The selection of study sites was systematic to ensure a representative sample of each land use type.

2.3. Sampling Techniques

The following sampling techniques where employed in data collection from the various experimental sites in order to test the research objectives and obtain desired results

2.3.1. Ecological Survey for Seedling Emergence or Seed Bank Analysis

In each plot, four quadrats were selected to collect soil seed bank samples at varying depths. A soil auger was used to obtain samples from the seven plots, ensuring a representative collection. A total of 21 cores were taken to represent the plots, with samples gathered at depths of 0-5 cm, 6-10 cm, and 11-15 cm [19]. To prevent heat and moisture damage, samples were stored in shaded bags and air-dried in the field [19]. The soil cores from each depth were then combined to form composite samples, which were used to estimate the abundance of Poaceae species using seed emergence techniques [20].

Each subsample was processed using the seedling emergence method, where the soil was spread thinly in trays and monitored for sprouting seedlings [21]. Identified seedlings were recorded and removed, while unidentified ones were retained for further identification using *Flora of West Africa* by Hutchinson and Dalziel [22]. The soil was stirred weekly and watered to ensure all viable seeds had the chance to germinate [23]. Over a six-month period, the seedlings were counted and identified, with unidentified species sent to a laboratory for further analysis [24].

Germination studies were employed to assess seed bank composition [25]. Although extraction methods are considered more accurate for estimating total seed bank density, they were not used due to time constraints and the risk of overestimating viability [26]. The seedling emergence method, commonly used for such studies, provided an effective estimation of readily germinable seeds [27]. To optimize conditions, coarse debris was removed from the samples, and trays were watered daily to prevent contamination [28]. The soil was stirred regularly over four months to ensure all seeds had the opportunity to germinate. The total number of emerged seedlings was used to estimate viable seed density [29].

3. RESULTS

The evaluation of seed bank status in experimental plots uncovered a collective presence of 15 species seed banks from the seven study plots, as depicted in Table 9. Among these 15 seed banks, 4 belong to the Poaceae family, while the remaining 11 are distributed among various other families

SN	Species name	Family
1	*Amaranthus blitum*	Amaranthaceae
2	*Aristolochia serpentaria*	Aristolochiaceae
3	*Ageratum conyzoides*	Asteraceae
4	*Cleome viscose*	Capparaceae
5	*Cyperus rotundus*	Cyperaceae
6	*Euphobia hirta*	Euphobiaceae
7	*Desmodium trifolium*	Fabaceae
8	*Peperomia pellucid*	Piperaceae
9	*Cynodon dactylon*	Poaceae
10	*Digitaria sanguinalis*	Poaceae
11	*Panicum maximum*	Poaceae
12	*Setaria viridis*	Poaceae
13	*Portulaca oleracea*	Portulacaceae
14	*Edrastima uniflora*	Rubiaceae
15	*Capiscum annum*	Solanaceae

The distribution of seed banks in different soil depths displayed clear patterns. The moderately grazed site contained 11 out of 15 seed bank species (73%) at a depth of 0-5cm, while the heavily grazed site had the lowest with only 4 species (27%).

In the 6-10cm soil depth, the moderately grazed plot, abandoned farmland, and annual watershed plot each showed 7 seed bank species (47%) out of 15, while the other four sites only had 4 seed bank species (27%).

At a depth of 11-15cm, abandoned farmland had the highest number of seed bank species with 7 (47%), while the heavily grazed site and footpath had the lowest with 2 species (13%).

The results from binary logistic regression revealed that the distribution of the 15 sampled seed bank species significantly varied by sites, depth, and family type ($p<0.05$). Specifically, the likelihood of annual watershed and abandoned farmland sites having more seed bank species is significantly higher compared to the moderately grazed site ($p<0.05$). Similarly, the probability of finding more seed bank species at a depth of 0-5 cm is significantly greater compared to the depth of 11-15 cm. Furthermore, the chance of encountering seed bank species from other families is significantly higher compared to those from the Poaceae family.

Table 2. *Distribution of Seed banks across various study plot at depth of 0-5 cm*

SN	Species name	Family	Site1: Heavily Grazed	Site 2: Moderately Grazed	Site3: Roadside	Site 4: Abandoned Farmland	Site 5: Footpath	Site 6: Annual Watershed	Site 7: Perennial Watershed
1	*Amaranthus blitum*	Amaranthaceae		⁑		⁑	⁑		
2	*Aristolochia serpentaria*	Aristolochiaceae			⁑			⁑	⁑
3	*Ageratum conyzoides*	Asteraceae					⁑	⁑	
4	*Cleome viscose*	Capparaceae		⁑			⁑		
5	*Cyperus rotundus*	Cyperaceae	⁑	⁑	⁑	⁑	⁑	⁑	
6	*Euphobia hirta*	Euphobiaceae			⁑		⁑		
7	*Desmodium trifolium*	Fabaceae		⁑	⁑	⁑	⁑		⁑
8	*Peperomia pellucid*	Piperaceae		⁑		⁑			
9	*Cynodon dactylon*	Poaceae		⁂		⁂	⁂	⁂	
10	*Digitaria sanguinalis*	Poaceae	⁂	⁂		⁂	⁂	⁂	⁂
11	*Panicum maximum*	Poaceae		⁂					
12	*Setaria viridis*	Poaceae	⁂	⁂	⁂	⁂	⁂	⁂	⁂
13	*Portulaca oleracea*	Portulacaceae				⁑			
14	*Edrastima uniflora*	Rubiaceae		⁑					
15	*Capiscum annum*	Solanaceae	⁑	⁑	⁑	⁑		⁑	⁑
	Total encountered spp		4	11	6	9	9	7	5
	%		27%	73%	40%	60%	60%	47%	33%

Key: ⁂*- Poaceae* , ⁑ *Other Family*

Table 3. *Distribution of Seed banks across various study plot at depth of 6-10 cm*

SN	Species name	Family	Site1: Heavily Grazed	Site 2: Moderately Grazed	Site 3: Roadside	Site 4: Abandoned Farmland	Site5: Footpath	Site 6: Annual Watershed	Site 7: Perennial Watershed
1	*Amaranthus blitum*	Amaranthaceae				⁑			
2	*Aristolochia serpentaria*	Aristolochiaceae			⁑	⁑			
3	*Ageratum conyzoides*	Asteraceae							
4	*Cleome viscose*	Capparaceae		⁑				⁑	
5	*Cyperus rotundus*	Cyperaceae	⁑	⁑		⁑	⁑	⁑	
6	*Euphobia hirta*	Euphobiaceae							
7	*Desmodium trifolium*	Fabaceae		⁑		⁑	⁑	⁑	⁑
8	*Peperomia pellucid*	Piperaceae							
9	*Cynodon dactylon*	Poaceae			⁂			⁂	
10	*Digitaria sanguinalis*	Poaceae	⁂	⁂	⁂	⁂	⁂	⁂	⁂
11	*Panicum maximum*	Poaceae							
12	*Setaria viridis*	Poaceae	⁂	⁂	⁂	⁂	⁂	⁂	⁂
13	*Portulaca oleracea*	Portulacaceae							
14	*Edrastima uniflora*	Rubiaceae		⁑					
15	*Capiscum annum*	Solanaceae	⁑	⁑		⁑		⁑	⁑
	Total encountered spp		4	7	4	7	4	7	4
	%		27%	47%	27%	47%	27%	47%	27%

Key: ⁂*- Poaceae* , ⁑ *Other Family*

Table 4. *Distribution of Seed banks across various study plot at depth of 11-15 cm*

SN	Species name	Family	Site1: Heavily Grazed	Site 2: Moderately Grazed	Site 3: Road side	Site 4: Abandoned Farmland	Site5: Foot path	Site 6: Annual Watershed	Site 7: Perennial Watershed
1	*Amaranthus blitum*	Amaranthaceae				⁑			
2	*Aristolochia serpentaria*	Aristolochiaceae			⁑	⁑			
3	*Ageratum conyzoides*	Asteraceae							
4	*Cleome viscose*	Capparaceae							
5	*Cyperus rotundus*	Cyperaceae		⁑	⁑	⁑	⁑	⁑	
6	*Euphobia hirta*	Euphobiaceae							
7	*Desmodium trifolium*	Fabaceae		⁑		⁑			
8	*Peperomia pellucid*	Piperaceae							
9	*Cynodon dactylon*	Poaceae			⁂			⁂	
10	*Digitaria sanguinalis*	Poaceae	⁂	⁂	⁂	⁂		⁂	⁂
11	*Panicum maximum*	Poaceae							
12	*Setaria viridis*	Poaceae	⁂	⁂	⁂	⁂	⁂	⁂	⁂
13	*Portulaca oleracea*	Portulacaceae							

14	*Edrastima uniflora*	Rubiaceae		⁑					
15	*Capiscum annum*	Solanaceae		⁑		⁑		⁑	⁑
	Total encountered spp		2	6	5	7	2	5	3
	%		13%	40%	33%	47%	13%	33%	20%

Key: ⁂- *Poaceae* ⁑ *Other Family*

Table 5. *Binary Regression Output of seed bank availability (presence or absent) and independent variables (sites, depth, and family)*

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Sites			16.876	6	.010			
	Sites (PW)	.268	.519	.267	1	.605	1.308	.473	3.617
	Sites (AW)	1.053	.497	4.490	1	.034	2.865	1.082	7.585
	Sites (AF)	1.455	.495	8.630	1	.003	4.283	1.623	11.304
	Sites (RS)	.625	.505	1.530	1	.216	1.869	.694	5.033
	Sites (FP)	.736	.502	2.146	1	.143	2.088	.780	5.589
	Sites (MG)	1.554	.496	9.830	1	.002	4.731	1.791	12.501
	Sites (HG) +								
	Depth			9.532	2	.009			
	Depth (0-5)	.934	.312	8.945	1	.003	2.546	1.380	4.696
	Depth (6-10)	.300	.317	.895	1	.344	1.349	.725	2.511
	Depth (11-15) +								
	Family (Others)	-1.364	.281	23.482	1	.000	.256	.147	.444
	Family (Poaceae)+								
	Constant	-.798	.454	3.082	1	.079	.450		
a. Variable(s) entered on step 1: Sites, Depth, Family									

Seed Bank Abundance Status of the Experimental Site

In Table 6-12, the density of different seed bank species by site and depth was also shown. *Setaria viridis* was found to have the highest abundant seed bank across the three soil depths at the heavily grazed site.

At the moderately grazed site, *Digitaria sanguinalis* was the most abundant seed bank at 0-5cm depth, *Cyperus rotundus* at 6-10 cm depth, and *Edrastima uniflora* at 11-15 cm depth.

The roadside study site revealed *Capiscum annum* as the most abundant seed bank at 0-5cm depth, *Cynodon dactylon* at 6-10 cm depth, and *Aristolochia serpentaria*, *Cyperus rotundus*, and *Digitaria sanguinalis* as the most abundant seed bank at 11-15 cm depth.

Additional findings showed that *Setaria viridis* was the most abundant seed bank across the three soil depths of the abandoned farmland site, while *Digitaria sanguinalis* was the most abundant seed bank across the three soil depths of the footpath site.

In the annual watershed site, *Setaria viridis* was the most abundant seed bank across the three soil depths, and in the perennial watershed site, *Digitaria sanguinalis* was the most abundant species at soil depths of 0-5 cm and 6-10 cm, while *Setaria viridis* was the most abundant seed bank at 11-15 cm depth.

Overall, the moderately grazed site had the highest seed bank density of 26 seeds per square meter, while the roadside experimental site had the lowest seed bank density of 2 seeds per square meter (Fig 1). The analysis of variance shows that soil depth significantly contributes to the variation in seed bank density, while sites do not.

Table 6. *Seed bank Abundance Status of Heavily Grazed Site*

			0-5 cm		6-10 cm		11-15 cm	
S/ No	Plant Species	Family	Density (M^2)	Rel Density(%)	Density (M^2)	Rel Density(%)	Density (M^2)	Rel Density(%)
1	*Amaranthus blitum*	Amaranthaceae	-	-	-	-	-	-
2	*Aristolochia serpentaria*	Aristolochiaceae	-	-	-	-	-	-
3	*Ageratum conyzoides*	Asteraceae	-	-	-	-	-	-
4	*Cleome viscose*	Capparaceae	-	-	-	-	-	-

5	*Cyperus rotundus*	Cyperaceae	1.06	3.5%	1.70	6.2%	-	-
6	*Euphobia hirta*	Euphobiaceae	-	-	-	-	-	-
7	*Desmodium trifolium*	Fabaceae	-	-	-	-	-	-
8	*Peperomia pellucida*	Piperaceae	-	-	-	-	-	-
9	*Digitaria sanguinalis*	Poaceae	0.42	1.4%	1.70	6.2%	0.42	18.2%
10	*Setaria viridis*	Poaceae	27.80	91.0%	18.46	66.9%	1.91	81.8%
11	*Cynodon dactylon*	Poaceae	-	-	-	-	-	-
12	*Panicum maximum*	Poaceae	-	-	-	-	-	-
13	*Portulaca oleracea*	Portulacaceae	-	-	-	-	-	-
14	*Edrastima uniflora*	Rubiaceae	-	-	-	-	-	-
15	*Capiscum annum*	Solanaceae	1.27	4.2%	5.73	20.8%	-	-
		Total	30.56	100.0%	27.59	100.0%	2.33	100.0%

Table 7. *Seed bank Abundance Status of Moderately Grazed Site*

			0-5 cm		6-10 cm		11-15 cm	
S/ No	Plant Species	Family	Density (M^{-2})	Rel Density (%)	Density (M^{-2})	Rel Density (%)	Density (M^{-2})	Rel Density (%)
1	*Amaranthus blitum*	Amaranthaceae	0.21	0.4%	-	-	-	-
2	*Aristolochia serpentaria*	Aristolochiaceae	-	-	-	-	-	-
3	*Ageratum conyzoides*	Asteraceae	-	-	-	-	-	-
4	*Cleome viscose*	Capparaceae	0.21	0.4%	0.21	2.3%	-	-
5	*Cyperus rotundus*	Cyperaceae	2.55	4.4%	2.12	23.3%	1.70	15.7%
6	*Euphobia hirta*	Euphobiaceae	-	-	-	-	-	-
7	*Desmodium trifolium*	Fabaceae	15.49	27.0%	1.70	18.6%	4.24	39.2%
8	*Peperomia pellucid*	Piperaceae	0.21	0.4%	-	-	-	-
9	*Digitaria sanguinalis*	Poaceae	18.25	31.9%	1.49	16.3%	1.27	11.8%
10	*Setaria viridis*	Poaceae	2.12	3.7%	1.06	11.6%	0.21	2.0%
11	*Cynodon dactylon*	Poaceae	0.64	1.1%	-	-	-	-
12	*Panicum maximum*	Poaceae	0.64	1.1%	-	-	-	-
13	*Portulaca oleracea*	Portulacaceae	-	-	-	-	-	-
14	*Edrastima uniflora*	Rubiaceae	12.73	22.2%	1.91	20.9%	2.55	23.5%
15	*Capiscum annum*	Solanaceae	4.24	7.4%	0.64	7.0%	0.85	7.8%
		Total	57.30	100.0%	9.12	100.0%	10.82	100.0%

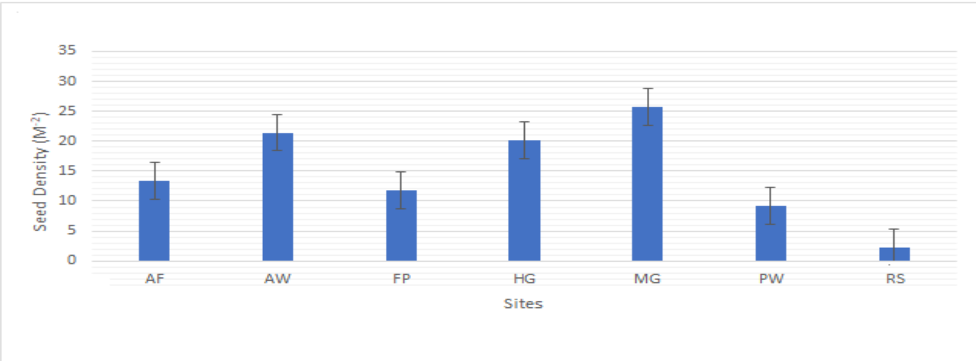


Fig 1. *Average seed bank density of the experimental sites*

Table 8. *Seed bank Abundance Status of Roadside Site*

			0-5 cm		6-10 cm		11-15 cm	
S/ No	Plant Species	Family	Density (M^2)	Rel Density (%)	Density (M^{-2})	Rel Density (%)	Densit y (M^{-2})	Rel Density (%)
1	*Amaranthus blitum*	Amaranthaceae	-	-	-	-	-	-
2	*Aristolochia serpentaria*	Aristolochiaceae	0.42	15.4%	0.42	22.2%	0.64	27.3%
3	*Ageratum conyzoides*	Asteraceae	-	-	-	-	-	-
4	*Cleome viscose*	Capparaceae	-	-	-	-	-	-
5	*Cyperus rotundus*	Cyperaceae	0.21	7.7%	-	-	0.64	27.3%
6	*Euphobia hirta*	Euphobiaceae	0.42	15.4%	-	-	-	-

7	*Desmodium trifolium*	Fabaceae	0.21	7.7%	-	-	-	-
8	*Peperomia pellucida*	Piperaceae	-	-	-	-	-	-
9	*Digitaria sanguinalis*	Poaceae	-	-	0.42	22.2%	0.64	27.3%
10	*Setaria viridis*	Poaceae	0.21	7.7%	0.21	11.1%	0.21	9.1%
11	*Cynodon dactylon*	Poaceae	-	-	0.85	44.4%	0.21	9.1%
12	*Panicum maximum*	Poaceae	-	-	-	-	-	-
13	*Portulaca oleracea*	Portulacaceae	-	-	-	-	-	-
14	*Edrastima uniflora*	Rubiaceae	-	-	-	-	-	-
15	*Capiscum annum*	Solanaceae	1.27	46.2%	-	-	-	-
		Total	2.76	100.0%	1.91	100.0%	2.33	100.0%

Table 9. *Seed bank Abundance Status of Abandon Farmland Site*

			0-5 cm		6-10 cm		11-15 cm	
S/No	Plant Species	Family	Density (M^2)	Rel Density (%)	Density (M^{-2})	Rel Density (%)	Density (M^{-2})	Rel Density (%)
1	*Amaranthus blitum*	Amaranthaceae	-	-	-	-	-	-
2	*Aristolochia serpentaria*	Aristolochiaceae	0.42	15.4%	0.42	22.2%	0.64	27.3%
3	*Ageratum conyzoides*	Asteraceae	-	-	-	-	-	-
4	*Cleome viscose*	Capparaceae	-	-	-	-	-	-
5	*Cyperus rotundus*	Cyperaceae	0.21	7.7%	-	-	0.64	27.3%
6	*Euphobia hirta*	Euphobiaceae	0.42	15.4%	-	-	-	-
7	*Desmodium trifolium*	Fabaceae	0.21	7.7%	-	-	-	-
8	*Peperomia pellucida*	Piperaceae	-	-	-	-	-	-
9	*Digitaria sanguinalis*	Poaceae	-	-	0.42	22.2%	0.64	27.3%
10	*Setaria viridis*	Poaceae	0.21	7.7%	0.21	11.1%	0.21	9.1%
11	*Cynodon dactylon*	Poaceae	-	-	0.85	44.4%	0.21	9.1%
12	*Panicum maximum*	Poaceae	-	-	-	-	-	-
13	*Portulaca oleracea*	Portulacaceae	-	-	-	-	-	-
14	*Edrastima uniflora*	Rubiaceae	-	-	-	-	-	-
15	*Capiscum annum*	Solanaceae	1.27	46.2%	-	-	-	-
		Total	2.76	100.0%	1.91	100.0%	2.33	100.0%

Table 10. *Seed bank Abundance Status of Footpath Site*

			0-5 cm		6-10 cm		11-15 cm	
S/No	Plant Species	Family	Density (M^2)	Rel Density (%)	Density (M^{-2})	Rel Density (%)	Densit y (M^2)	Rel Density (%)
1	*Amaranthus blitum*	Amaranthaceae	0.85	3.6%	-	-	-	-
2	*Aristolochia serpentaria*	Aristolochiaceae	-	-	-	-	-	-
3	*Ageratum conyzoides*	Asteraceae	0.21	0.9%	-	-	-	-
4	*Cleome viscose*	Capparaceae	0.42	1.8%	-	-	-	-
5	*Cyperus rotundus*	Cyperaceae	6.79	28.8%	2.12	22.2%	0.21	9.1%
6	*Euphobia hirta*	Euphobiaceae	0.42	1.8%	-	-	-	-
7	*Desmodium trifolium*	Fabaceae	1.27	5.4%	1.06	11.1%	-	-
8	*Peperomia pellucid*	Piperaceae	-	-	-	-	-	-
9	*Digitaria sanguinalis*	Poaceae	11.46	48.6%	6.15	64.4%	1.70	72.7%
10	*Setaria viridis*	Poaceae	1.06	4.5%	0.21	2.2%	0.42	18.2%
11	*Cynodon dactylon*	Poaceae	1.06	4.5%	-	-	-	-
12	*Panicum maximum*	Poaceae	-	-	-	-	-	-
13	*Portulaca oleracea*	Portulacaceae	-	-	-	-	-	-
14	*Edrastima uniflora*	Rubiaceae	-	-	-	-	-	-
15	*Capiscum annum*	Solanaceae	-	-	-	-	-	-
		Total	23.55	100.0%	9.55	100.0%	2.33	100.0%

Table 11. *Seed bank Abundance Status of Annual Watershed Site*

			0-5 cm		6-10 cm		11-15 cm	
S/ No	Plant Species	Family	Density (M^2)	Rel Density (%)	Density (M^{-2})	Rel Density (%)	Density (M^{-2})	Rel Density (%)
1	*Amaranthus blitum*	Amaranthaceae	-	-	-	-	-	-

2	*Aristolochia serpentaria*	Aristolochiaceae	0.21	0.8%	-	-	-	-
3	*Ageratum conyzoides*	Asteraceae	0.21	0.8%	-	-	-	-
4	*Cleome viscose*	Capparaceae	-	-	-	-	0.21	1.4%
5	*Cyperus rotundus*	Cyperaceae	2.76	10.6%	4.24	18.9%	3.40	21.6%
6	*Euphobia hirta*	Euphobiaceae	-	-	-	-	-	-
7	*Desmodium trifolium*	Fabaceae	-	-	-	-	0.42	2.7%
8	*Peperomia pellucida*	Piperaceae	-	-	-	-	-	-
9	*Digitaria sanguinalis*	Poaceae	7.22	27.6%	1.91	8.5%	0.64	4.1%
10	*Setaria viridis*	Poaceae	7.43	28.5%	12.94	57.5%	8.91	56.8%
11	*Cynodon dactylon*	Poaceae	7.43	28.5%	1.91	8.5%	0.85	5.4%
12	*Panicum maximum*	Poaceae	-	-	-	-	-	-
13	*Portulaca oleracea*	Portulacaceae	-	-	-	-	-	-
14	*Edrastima uniflora*	Rubiaceae	-	-	-	-	-	-
15	*Capiscum annum*	Solanaceae	0.85	3.3%	1.49	6.6%	1.27	8.1%
		Total	26.10	100.0%	22.49	100.0%	15.70	100.0%

Table 12. *Seed bank Abundance Status of Perennial Watershed Site*

			0-5 cm		6-10 cm		11-15 cm	
S/No	Plant Species	Family	Density (M^{-2})	Rel Density (%)	Density (M^{-2})	Rel Density (%)	Density (M^{-2})	Rel Density (%)
1	*Amaranthus blitum*	Amaranthaceae	-	-	-	-	-	-
2	*Aristolochia serpentaria*	Aristolochiaceae	-	-	1.27	8.7%	-	-
3	*Ageratum conyzoides*	Asteraceae	-	-	-	-	-	-
4	*Cleome viscose*	Capparaceae	-	-	-	-	-	-
5	*Cyperus rotundus*	Cyperaceae	-	-	-	-	-	-
6	*Euphobia hirta*	Euphobiaceae	-	-	-	-	-	-
7	*Desmodium trifolium*	Fabaceae	2.33	23.4%	1.49	10.1%	-	-
8	*Peperomia pellucida*	Piperaceae	-	-	-	-	-	-
9	*Digitaria sanguinalis*	Poaceae	3.18	31.9%	8.28	56.5%	0.64	21.4%
10	*Setaria viridis*	Poaceae	2.55	25.5%	3.18	21.7%	1.49	50.0%
11	*Cynodon dactylon*	Poaceae	-	-	-	-	-	-
12	*Panicum maximum*	Poaceae	-	-	-	-	-	-
13	*Portulaca oleracea*	Portulacaceae	-	-	-	-	-	-
14	*Edrastima uniflora*	Rubiaceae	-	-	-	-	-	-
15	*Capiscum annum*	Solanaceae	1.91	19.1%	0.42	2.9%	0.85	28.6%
		Total	9.97	100.0%	14.64	100.0%	2.97	100.0%

Seed Bank Diversity of the Experimental Sites

The calculation of Shannon Weiner's Index of diversities for each site and soil depth is summarised in Table 13. The diversity of seed banks across the experimental sites varied by soil depth, with equitability values ranging from 0.285 to 0.988. Specifically, the seed bank diversity of heavily grazed, roadside, footpath and perennial watershed sites were highest at the soil depth of 10-15 cm. The seed bank diversity of moderately grazed and abandoned farmland was highest at the soil depth of 6-10 cm while the seed bank diversity of the annual watershed was highest at the soil depth of 0-5 cm.

An analysis of variance revealed a significant difference in the Shannon Weiner's Index of diversities of the seed bank with respect to sites and depth ($p<0.05$).

Table 13. *Shannon Weiner's Index of Diversities of Seed bank of the Experimental Sites*

Soil Depth	0-5 cm		6-10 cm		10-15 cm	
Plot	H^1	Equitability	H^1	Equitability	H^1	Equitability
HG	0.395	0.285	0.938	0.677	0.474	0.684
MG	1.668	0.696	1.798	0.924	1.527	0.852
RS	1.525	0.851	1.273	0.918	1.499	0.931
AF	1.864	0.848	1.676	0.861	1.593	0.819
FP	1.453	0.661	0.946	0.683	0.760	0.691
AW	1.498	0.770	1.231	0.765	1.300	0.668
PW	1.201	0.747	1.369	0.988	1.035	0.942

4. DISCUSSION

The results from the study on soil seed bank dynamics across different ecosystems at Nnamdi Azikiwe University, Awka and Amansea provide valuable insights into species richness and seed bank distribution. A total of 15 species were identified from the seven study plots, with four species belonging to the Poaceae family, while the remaining 11 were distributed across other plant families. The data reveal a complex pattern of seed bank richness and distribution, influenced by both the depth of soil and the level of environmental disturbance within each site.

The most abundant species in the soil seed bank varied by site and soil depth. For example, *Setaria viridis* was found to be the most dominant species across all soil depths in abandoned farmland, while *Digitaria sanguinalis* was more prevalent in moderately grazed and footpath sites. The study also highlighted the importance of soil depth in seed bank composition. Shallow soil layers (0-5 cm) had the highest species richness, particularly in moderately grazed sites, while deeper layers (11-15 cm) showed a decrease in both seed abundance and species richness.

One significant finding is that the moderately grazed site recorded the highest overall seed bank density with 26 seeds per square meter, indicating that moderate grazing may create favorable conditions for seed bank formation. In contrast, the roadside site had the lowest seed bank density with only 2 seeds per square meter, likely due to greater environmental disturbances.

Binary logistic regression analysis further showed that seed bank presence and species composition were significantly influenced by site, soil depth, and plant family. The odds of encountering seed bank species in certain sites (e.g., annual watershed and abandoned farmland) were higher than in others, and species richness decreased with increasing soil depth. This underscores the ecological importance of both vertical and horizontal variations in seed bank distribution, which can affect vegetation recovery and ecosystem resilience.

The analysis of the distribution of seed banks at the research sites showed that a total of 15 plant species were present across the seven study locations and three soil depths. Out of these, 4 species were from the Poaceae family, and the remaining 11 were distributed among different families. A separate study on seed banks by Chengere *et al*. [19] found 74 plant species in the soil seed bank, representing 55 genera and 23 families. These results indicate that the seed banks in different study locations contain families other than Poaceae. In general, this study found that the list of seed bank species and the number of seeds per square meter decreased as the soil depth increased, and there were slight variations in the seed bank between locations. The findings of the study by Tóth *et al*. [20] support these results, demonstrating that seed density and species richness in the seed bank decreased with increasing soil depth. Additionally, it was observed that abandoned farms and moderately grazed locations harbored more seed bank species, with moderately grazed locations having the highest number of seeds per square meter. Fenetahun [21] suggested that reduced grazing intensity and seed trapping by farm animals make it easier for moderately grazed sites to harbor high numbers of seed banks. Zhao et al. [22] also pointed out that farming activities lead to the burial of weed seeds, which explains why abandoned farmland may contain more seed bank species.

Each site showed distinct differences in their most abundant seed bank species based on location and soil depth. *Setaria viridis* was the most prevalent species in abandoned farms, annual watershed ecosystems, and heavily grazed locations across the three soil depths. *Digitaria sanguinalis* was most abundant in footpath locations and perennial watersheds. Furthermore, *Digitaria sanguinalis* was one of the most abundant seed bank species in moderately grazed locations at a depth of 0-5 cm and in roadside ecosystems at a depth of 11-15 cm. The prevalence of *Setaria viridis* and *Digitaria sanguinalis* across the study locations suggests that the Poaceae family may have greater seed bank richness compared to other families. Borokini [23] demonstrated that most Poaceae species are invasive and competitive in nature and are generally considered stubborn weeds.

Interestingly, all study locations exhibited diversity in Poaceae species, with equitability values close to 1. However, perennial watershed ecosystems and abandoned farms had more species diversity than other study locations. This finding contradicts the study by Plieninger *et al*. [24], which found that abandoned farmland had lower Poaceae species richness compared to natural grasslands, indicating the dominance of a few competitive species. However, the findings of this study align with Vécrin and

Jacquemart [25], who found that abandoned farm land had a higher proportion of agricultural weed species in the seed bank compared to native grassland remnants.

In contrast to above-ground diversities, the study revealed that roadside locations had the highest seed bank diversity, while heavily grazed ecosystems had the lowest seed bank diversity. These findings underscore the importance of considering land management strategies when assessing the ecological dynamics of Poaceae and the soil seed bank [26]. Parks and Davis [27] noted that roadside habitats showed high species turnover and a mix of native and non-native Poaceae species. Continuous disturbance and exposure to various stressors in roadside environments could contribute to this dynamic species composition.

The study found that the highest diversity of seed banks was observed at a depth of 10-15 cm, followed by 6-10 cm and then 0-5 cm in most locations. It has been explained that at shallow depths, human and climatic factors such as flooding, grazing, and farming are more likely to disturb seed banks, leading to exposure and loss of buried seeds. On the other hand, at greater depths, the composition of seed banks is more likely to be stable and evenly distributed due to reduced disturbance. Each study site exhibited distinct dominant Poaceae species, indicating that no single species can adequately represent all areas. Therefore, identifying dominant Poaceae species for each study area may require a site-specific approach.

In terms of seed banks, both the species list and individual species decreased as soil depth increased. This suggests that ecologists may find shallow depths more productive when sampling seed banks efficiently. Abandoned farms and moderately grazed areas hosted a greater diversity of seed bank species, with moderately grazed areas also exhibiting a higher seed density per square meter compared to other locations. This indicates that abandoned farms and moderately grazed areas could be better sources of seed banks than other locations.

5. Conclusion

Variations in the distribution and abundance of Poaceae were observed across different study areas. Higher numbers of Poaceae species were found in perennial watersheds, annual watersheds, roadsides, and footpaths compared to sites affected by cattle grazing and abandoned farms. This suggests that researchers focusing on grazing sites and abandoned farms may encounter limitations when attempting to sample a wider range of Poaceae species for ecological studies.

Setaria viridis and *Digitaria sanguinalis* were found to be more prevalent in different study areas and at varying depths. Further study is needed to explore the adaptive or competitive abilities of these plant species. Perennial watershed ecosystems and abandoned farms, in general, exhibited greater diversity in above-ground species compared to other study locations, while the roadside location had the highest seed bank diversity. Additionally, while the number of seed banks decreased with increasing depth in most sites, seed bank diversity increased with depth. This finding may be valuable for future researchers interested in characterizing above-ground diversity and seed bank diversity in various ecosystems.

In summary, the results underscore the importance of considering both soil depth and land use type in ecological restoration efforts, particularly for maintaining diverse and resilient plant communities.

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Citation: *Iroka, F. Chisom et al. Spatial and Depth-Related Variability of Soil Seed Banks in Relation to Land Use and Environmental Disturbance: A Case Study of Poaceae Dominance in Tropical Ecosystems. International Journal of Advanced Research in Botany. 2024; 8(1):1-13. DOI: http://dx.doi.org/10.20431/2453-4316.0801001.*