

PLANT DIVERSITY AT SELECTED DUMPSITES IN ABAKALIKI: EXPLORING SPECIES TOLERANCE AND CARBON STORAGE FUNCTIONS

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ABSTRACT. The aim of this study was to determine the species diversity and carbon storage potential of herbaceous plants growing within selected dumpsites in the Abakaliki metropolis. The line transect method was used to collect plants from five study stations: Waterworks (A), Kpirikpiri (B), Newlayout (C), FETHA (D) and Presco (E). At each study station, a 15 m×30 m area was measured using tape and demarcated with pegs and ropes. The identified species were collected, the biomass, species frequency, density, dominance, diversity and carbon uptake were measured. The diversity indices evaluated showed that active dump station A was the most diverse and evenly distributed site (Shannon–Weiner diversity index: A=2.43, B=1.09, C=1.16, D=1.14, E=0.99, Pileou’s evenness index, A=1.53, B=0.70, C=0.68, D=0.66, E=0.69). Additionally, at station D, Simpson’s

dominance (A=0.27, B=0.32, C=0.24, D=0.43, E=0.10) and Magalef (species richness) indices (A=1.7, B=4.07, C=3.75, D=4.20, E=3.38) were the highest. The herbaceous *Ghomphrena celeisoides* had the highest relative dominance, relative frequency and important value index across the studied stations. Analysis of variance of the carbon uptake potentials of species showed significant values for abandoned dump stations C (Newlayout) and D (FETHA) when $p<0.05$. Therefore, total sequestered carbon in stations C ($F=15.97$, $p<0.001$) and D ($F=8.33$, $p<0.001$) and sequestered carbon dioxide equivalent at stations C ($F=15.96$, $p<0.001$) and D ($F=43.68$, $p<0.001$) were significant at 95% confidence level. The results indicate that species at dormant waste disposal sites sequester significant amounts of carbon; therefore, they are recommended for the



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phytoremediation of disturbed or destroyed ecosystems.

Keywords: carbon uptake; density; diversity; relative frequency.

INTRODUCTION

The floristic study of plants growing in open waste disposal sites provides useful information on the impacts of pollutants on the biodiversity of plant communities in the ecosystem and can serve as bioindicators for ecosystem quality assessment (Singh *et al.*, 2024). Several fluxes in waste and cover materials end up at the dump ground, creating an opportunity for some plant species to thrive abundantly while others become rare or absent (Nagendran *et al.*, 2006).

The measurement of abiotic factors, such as the rate of absorption and accumulation of mineral elements, play a significant role in the improvement of species composition at disposal sites (Pandey *et al.*, 2024). Non-biodegradable elements, such as cadmium, lead, copper, zinc and mercury, are found in waste soils during deposition and tend to enter the food chain of plants either from soil or water during active or passive transport enhanced by membrane-embedded ion channels (Nodza *et al.*, 2021). Potentially toxic elements are usually not metabolised by plants. Thus, heavy metal accumulation in plant tissues occurs mainly through the bio-concentration of elements in roots, stems, leaves and seeds, in some species. (Sliwa-Cebu *et al.*, 2020).

The ability of plants inhabiting polluted environments to bioaccumulate non-biodegradable pollutants is a criterion that supports the establishment of pollution thresholds (Eneji *et al.*, 2014;

Yin *et al.*, 2024). Plant species can remove and transfer pollutants from the roots to aerial parts, such as leaves and stems, thereby removing potentially toxic elements from the soil. This process is referred to as phytoremediation (Sharma *et al.*, 2023).

It is an economically and ecologically friendly strategy that optimises the high pollution tolerance, uptake and storage capacity of roots, stems and leaves and focuses on the transfer and stabilisation of pollutants in soil and ground water (Abenu *et al.*, 2021; Yakubu, 2017; Yan *et al.*, 2020).

Residents of the Abakaliki metropolis have an open waste disposal system. Over 42 million tonnes of waste are generated annually in the state. Thus, domestic and industrial wastes are deposited directly to these sites and constitute the following: biodegradable elements (44%), plastics (20%), metals (16%) and bottles (20%) (Nwagwu *et al.*, 2024).

Several methods have been explored in recent scientific investigations to remove potentially toxic elements from contaminated soils, including the introduction of hyperaccumulators in contaminated soils, the increase in biomass yield, the addition of chelators, the application of cytokinin, the electric field assistance method, microorganism inoculation and genetic engineering, all of which are cost effective and likely to introduce ecological risks associated with the increase of pollutants in the environment (Savaci and Oksuz, 2020).

Evaluation of the quantity of carbon sequestered in plants is both an economical and ecologically friendly strategy useful in monitoring the tolerance level of plants to pollutants

(Michael *et al.*, 2017). The benefits of organic carbon storage in plants include degraded ecosystem restoration and soil condition improvement. Carbon capture, allocation and storage are often not the only reason for species abundance and diversity in contaminated or polluted environments. It combines with other factors such as the soil pH balancing mechanism, root sink strength of nitrogen-fixing plants (legumes) and heavy metal bioaccumulation to produce a unique community of species tolerant to environmental stressors (Hachiya *et al.*, 2014). Few studies have focused on the species composition, diversity and carbon uptake levels in species inhabiting dumpsites. Some studies have emphasised the heavy metal distribution in soils, neglecting their impact on species distribution, diversity and ecology in polluted environments (Ikpe *et al.*, 2020; Savaci and Oksuz, 2020).

The aim of this study was to determine the diversity and carbon storage potential of plants growing within dumpsite ecosystems.

The specific objectives of this study were to:

- (1) Determine the species diversity, composition and abundance of plants growing within dumpsite environments.
- (2) Comparatively evaluate the organic carbon uptake in families of species encountered.
- (3) Identify species with high tolerance for potentially toxic pollutants in open waste disposal sites.

MATERIALS AND METHODS

Study area

This study was carried out in two active (Water-works and Kpirikpiri

Market) and two dormant (New-layout primary school and FETHA) dump sites in the Abakaliki metropolis from June 2023 to September 2023 during the rainy season.

The city is the capital of Ebonyi State and lies within latitude 6°15'N and 6°20'N and longitude 8°05'N and 8°10'E, with almost completely flat undulating land and about 120–180 m above sea level. The average temperature is 27°C, and the relative humidity is over 70%, with rainfall of approximately 2500 mm/year (Collins *et al.*, 2024).

Site description

In this study, two categories of dumpsites, active and dormant (inactive) were considered. An active dumpsite is an open land field where the dumping of refuse is actively practiced and officially designated by municipal authorities for residential dwellers in a particular area.

This study considered two active dumpsites. The first dumpsite was station A (waterworks), situated at the base of the popular Juju hills (Azugwu). The second active dumpsite was station B (KpiriKpiri), located adjacent to the famous Kpirikpiri market. The dormant or inactive waste dumpsites are locations formerly designated for public waste disposal.

Two dormant dumpsites were considered in this study. They were station C (Newlayout), located behind Newlayout Primary School, and station D (FETHA), situated in front of the Alex Ekwueme Teaching Hospital, Abakaliki, also known as the Federal Teaching Hospital Abakaliki (FETHA).

Station E is located beside the Amphitheatre at the College of Basic Medicine, inside Presco campus, Ebonyi

State University (EBSU), and it served as the control site in this work. The Presco location used has no history of waste disposal. *Figure 1* shows the locality and location of the study sites.

Sampling and data collection

A systematic sampling approach using the line transect method was employed. At each sampling site, a 15 m×30 m area was demarcated and measured (Andersen, 1993). Three 5-m linear transects with three 10-m intervals were marked in each location.

All plants that fell within the (9) sample plots were collected and labelled. Identification, weighing and oven drying were performed at the Department of Biological Sciences (EBSU). All species collected were identified to the species level using flora of west tropical Africa (Hutchinson and Dalziel, 1954). Plant structure and composition were evaluated in terms of frequency, abundance, diversity, density, species richness and evenness.

The biomass of species collected from each plot was weighed using an analytical digital balance SCOUT PRO (400 g/0.0001).

Data analysis

The species diversity indices and abundance at each site were determined and compared using one-way analysis of variance (ANOVA) and Duncan's multiple range test with the aid of the Statistical Programme for Social Science (SPSS).

Abundance

The abundance of species was determined by enumeration of the total number of individuals encountered at the site.

Relative abundance (%)

The relative abundance was calculated as the total number of individual species divided by the total number of species in the population multiplied by 100

Frequency (%)

The frequency of occurrence was calculated for each species using the following formula (*Equation 1*):

$$\text{Frequency (\%)} = \frac{\text{Total number of sample plots in which species occur}}{\text{Total number of sample plots studied}} \times 100 \quad (1)$$

Relative frequency (RF)

The relative frequency (RF) of each species was calculated using the following formula (*Equation 2*):

$$\text{RF} = \frac{\text{Number of occurrences of the species}}{\text{Number of occurrences of all species}} \times 100 \quad (2)$$

Density (plants/m²)

The density of each species was calculated per unit area using the following formula (*Equation 3*):

$$\text{Density (plants/m}^2\text{)} = \frac{\text{Total number of individuals of the species in all the sample units}}{\text{Total area of the sampling unit studied}} \times 100 \quad (3)$$

Relative density (RD)

The relative density (RD) of species was calculated using the following formula (*Equation 4*):

$$\text{RD (plants/m}^2\text{)} = \frac{\text{Number of individual species}}{\text{Total area of the sampling unit studied}} \times 100 \quad (4)$$

Dominance

Dominance was determined by calculating the total basal area of species.

Relative dominance (RDO)

The relative dominance (RDO) was determined using the following formula (Equation 5):

$$RDO = \frac{\text{Dominance}}{\text{Dominance of all species}} \times 100 \quad (5)$$

Important value index (IVI)

The importance value index (IVI) was calculated by summation of the values of relative density, relative frequency and relative dominance, as follows (Equation 6):

$$IVI = \frac{RF + RD + RDO}{3} \times 100 \quad (6)$$

Diversity indices

i. Magalef's index was determined using the following formula (Equation 7):

$$D = \frac{(s - 1)}{\log_{10} N} \quad (7)$$

where D is the diversity index; S is the number of species; and N is the number of individuals (Margalef, 1958).

ii. Shannon–Weiner diversity was determined using the following formula (Equation 8):

$$H = \sum (p_1 (\log p_1)) \quad (8)$$

where $P = \frac{n_i}{N}$ and H is the Shannon–Weiner index; n_i is the number of individual species; and N is the total number of individuals for all species (Shannon and Weiner, 1949).

iii. The Pileou species evenness index (E) was determined using the following formula (Equation 9):

$$E = \frac{N}{\text{Log} S} \quad (9)$$

where S is the number of species; and N is the total number of organisms of all species (Pielou, 1966).

iv. The Simpson diversity index was determined using the following formulas (Equation 10 and Equation 11):

$$H = \sum_{i=1}^s p_i \ln p_i \quad (10)$$

$$D = \frac{\sum n (n - 1)}{N (N - 1)} \quad (11)$$

where D is the Simpson index diversity; n is the total number of a particular species; and N is the total number of organisms of all species (Simpson, 1949).

Total sequestered carbon (TSC)

The total sequestered carbon (TSC) of herbs and grasses at each location were determined using the Schlesinger formula, as follows:

$$C = 0.475 \times B \quad (12)$$

where C is the oven dry carbon content of each species; 0.475 is a constant; and B is the oven dry biomass. C is mostly between 45 and 50% of dry biomass (Okunlola *et al.*, 2019).

Sequestered carbon dioxide estimate (SCO₂E)

The sequestered carbon dioxide estimate (SCO₂E) was calculated using the following formula:

$$TSC \times 3.67 \quad (13)$$

where TSC is the total sequestered carbon estimated in 2.5; and 3.67 is a constant and estimates the carbon dioxide in kg absorbed by a plant during its lifetime (Schlesinger and Amundson, 2018).

RESULTS

This study inventoried 79 species belonging to 25 families in 2 active and 2 dormant dumpsites in Abakaliki, Ebonyi State, Nigeria. Stations A (Waterworks) and B (Kpiripiri market) constituted the

active dumpsites, and stations C (Newlayout) and station D (FETHA) constituted the dormant dumpsites (where dumping activity had stopped). Station E (Presco) was the control site representing an environment where dumping activities had never been established. *Table 1* shows the distribution and abundance of species in each family. Poaceae was inventoried as the most abundant and accounted for 7 species at station A, 9 species at station B, 9 species at station C, 12 species at station D and 6 species at station E. The second most specious families were the Asteraceae and Cyperaceae. *Table 2* shows the list of species encountered and their phenology, habit and frequency of occurrence at each study location evaluated. *Table 3* shows the total relative frequency, relative density and important value indices of all individual species at stations A, B, C, D and E. The table is a summary of the species distribution, frequency and dominance. The relative frequency (RF) and diversity of species across study locations showed that the following species occurred the most across study locations: *Laportea aestuans*, *Physalis angulate* and *Portulaca oleracea* at station A; *Gomphrena celosoides* and *Eleusine indica* at station B; *Euphorbia hirta*, *Gomphrena celosoides* and *Eleusine indica* at station C; *Aspilia african*, *Ageratum conyzoides*, *Euphorbia hirta*, *Euphorbia heterophylla*, *Echinochloa crus-galli* and *Mimosa pudica* at station D; and *Amaranthus spinosus*, *Calapogonum mucunoides*, *Imperata cylindrica*, *Laportea ovalifolia*, *Sida acuta* and *Sida rhombifolia* at station E.

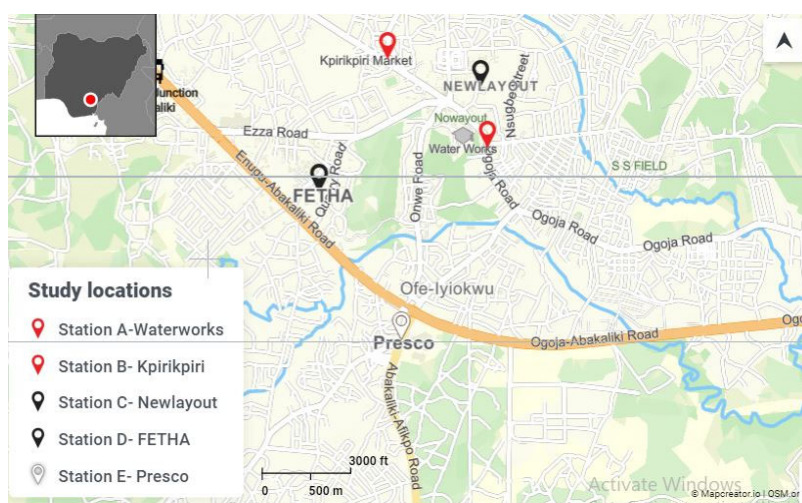
Ghomphrena celeisoides recorded the highest proportion of total relative

frequency (RF), (23.44%), Relative Density (RD), (14.81 plants/m²) and Relative Dominance (RDO), (29.67%) across all study locations. The important value index (IVI) across study locations revealed that the following species were the most important: *Ghomphrena celeisoides*, *Ageratum conyzoides*, *Euphorbia hirta* and *Amaranthus spinosus*. The most important grass species was *Eleusine indica*.

Table 4 and *Table 5* show the results of ANOVA and Duncan's multiple range test for RF and RD. RF and RD did not yield any significant differences at a 95% confidence interval ($p > 0.05$). Duncan's multiple range test reported the least significant difference (LSD) of the frequency of distribution as 0.95 and 0.74 for RD. At station E, the frequency of distribution and RD showed the highest mean and standard deviation, respectively. *Figure 2* shows the bar charts of species diversity indices evaluated at stations A, B, C, D and E in Abakaliki. Species richness was determined using the Magalef diversity index, which indicated that station D (FETHA) (4.20) had the richest species composition, followed by stations A (4.17), B (3.75), C (4.07) and E (3.38).

The Simpson's species dominance index showed that station D (0.43) hosted the most dominant species, followed by stations A (0.27), B (0.24), C (0.32) and E (0.10). The Shannon-Weiner diversity index revealed station A ($H' = 2.43$) as the most diverse location, followed by stations B ($H' = 1.09$), C ($H' = 1.16$), D ($H' = 1.14$) and E ($H' = 0.99$). Station A ($E = 1.51$) also had the most evenly distributed species compared to stations B ($E = 0.68$), C ($E = 0.70$), D ($E = 0.66$) and E ($E = 0.69$).

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Source: <https://mapcreator.io>

Figure 1 – Map of study locations in the Abakaliki Metropolis

Table 1 – Showing family composition and abundance for species encountered

Family/Station	Family Abundance					Species Composition %				
	A	B	C	D	E	A	B	C	D	E
Aizoaceae	1	1	0	1	0	2.44	2.44	0.00	2.44	0.00
Amaranthaceae	4	3	3	3	1	9.76	7.32	7.32	7.32	2.44
Asteraceae	6	4	4	5	5	14.63	9.76	9.76	12.2	12.2
Cleomaceae	0	0	1	1	0	0.00	0.00	2.44	2.44	0.00
Connaraceae	0	1	1	1	0	0.00	2.44	2.44	2.44	0.00
Convulvulaceae	1	1	1	1	1	2.44	2.44	2.44	2.44	2.44
Commelineaceae	1	3	3	3	2	2.44	7.32	7.32	7.32	4.88
Cucurbitaceae	1	1	2	1	0	2.44	2.44	4.88	2.44	0.00
Cyperaceae	1	4	4	5	0	2.44	9.76	9.76	12.2	0.00
Euphorbiaceae	4	3	4	4	1	9.76	7.32	9.76	9.76	2.44
Fabaceae	2	2	3	3	2	4.88	4.88	7.32	7.32	4.88
Lamiaceae	2	2	1	2	1	4.88	4.88	2.44	4.88	2.44
Loganaceae	1	0	0	0	0	2.44	0.00	0.00	0.00	0.00
Malvaceae	2	2	1	2	1	4.88	4.88	2.44	4.88	2.44
Myrtaceae	0	0	1	0	0	0.00	0.00	2.44	0.00	0.00
Onagraceae	0	1	1	0	0	0.00	2.44	2.44	0.00	0.00
Plantaginaceae	0	0	0	0	1	0.00	0.00	0.00	0.00	2.44
Portulacaceae	1	0	0	0	0	2.44	0.00	0.00	0.00	0.00
Phyllanthaceae	1	0	1	1	1	2.44	0.00	2.44	2.44	2.44
Polygonaceae	1	0	1	2	1	2.44	0.00	2.44	4.88	2.44
Poaceae	7	9	9	12	6	17.07	21.95	21.95	29.27	14.63
Solanaceae	2	1	1	1	0	4.88	2.44	2.44	2.44	0.00
Talinaceae	1	0	0	1	0	2.44	0.00	0.00	2.44	0.00
Urticaceae	1	1	3	3	2	2.44	2.44	7.32	7.32	4.88
Verbeaceae	1	0	0	0	0	2.44	0.00	0.00	0.00	0.00
Total number of species per plot	41	39	45	52	25					

Table 2 – Showing species phenology, habit and frequency of occurrence in Station A, B, C, D, E

S/ N	Species	Phenology	Habit	Active dumpsites		Dormant dumpsites		Con- trol
				A (Waterworks)	B (KpiriKpiri)	C (Newlayout)	D (FETHA)	E (Presco)
1	<i>Acalypha indica</i> L.	Bud bloom	Herb	3	0	7	10	17
2	<i>Acalypha wilkesiana</i> Mull.Arg	Bud bloom	Small Shrub	0	0	0	3	7
3	<i>Ambrosia artemisiifolia</i> L.	Bud bloom	Herb	7	0	2	0	7
4	<i>Amaranthus spinosus</i> L.	Bud bloom	Herb	10	13	10	10	20
5	<i>Amaranthus hybridus</i> L.	Bud bloom	Herb	0	0	0	7	0
6	<i>Aspilia Africana</i> (Pers.) C.D. Adams	Bud bloom	Herb	13	0	2	20	7
7	<i>Aspilia thouarsii</i> DC.	Bud bloom	Herb	0	0	0	10	0
8	<i>Ageratum conyzoides</i> L.	Bud bloom	Herb	13	7	17	20	10
9	<i>Aeschynomene indica</i> L.	Bud bloom	Herb	0	3	3	0	0
10	<i>Byrsocarpus coccineus</i> Schum. &Thonn.	Bud bloom	Herb	3	0	1	0	0
11	<i>Cyathulla prostrate</i> (L.) Blume	Bud bloom	Herb	3	0	0	3	0
12	<i>Corchorus olitorius</i> L.	Bud bloom	Herb	10	0	0	0	0
13	<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob	Bud bloom	Herb	7	0	3	0	3
14	<i>Chloris barbata</i> Sw.	Bud bloom	Herb	0	0	3	3	0
15	<i>Commelina communis</i> L.	Bud bloom	Herb	0	7	0	3	3
16	<i>Commelina diffusa</i> Burm.f.	Bud bloom	Herb	10	7	3	7	0
17	<i>Cyatnotis axillaris</i> (L.) D. Don ex Sweet	Bud bloom	Herb	0	3	0	7	0
18	<i>Cyperus deformis</i> L.	Bud bloom	Sedge	0	3	3	0	0
19	<i>Cyperus tenuispica</i> Steud.	Bud bloom	Sedge	0	10	13	13	0
20	<i>Cyperus iria</i> L.	Bud bloom	Sedge	3	7	0	0	0
21	<i>Cyperus rotundus</i> L.	Bud bloom	Sedge	0	0	13	0	0
22	<i>Cyperus compressus</i> L.	Bud bloom	Sedge	0	3	0	7	0
23	<i>Cyperus esculentus</i> L.	Bud bloom	Sedge	7	0	17	0	0
24	<i>Cleome viscosa</i> L.	Bud bloom	Herb	0	0	7	3	17
25	<i>Cleome rutidosperma</i> DC.	Bud bloom	Herb	0	7	3	3	0
26	<i>Calapogonum mucunoides</i> Desv.	Bud bloom	Herb	7	7	7	10	20
27	<i>Centrosema pubescens</i> Benth.	Bud bloom	Herb	0	3	0	7	0
28	<i>Digitaria sanguinalis</i> (L.) Scop	Bud bloom	Grass	0	0	1	10	10
29	<i>Emilia coccinea</i> (Sims.) G. Don.	Bud bloom	Grass	0	0	0	10	0
30	<i>Echinochloa crusgalli</i> (L.) P. Beauv.	Bud bloom	Grass	3	10	3	20	0
31	<i>Echinochloa colonum</i> (L.) Link.	Bud bloom	Grass	13	7	0	10	3
32	<i>Eleusine indica</i> (L.) Gaertn.	Bud bloom	Grass	17	20	20	3	0
33	<i>Euphorbia hirta</i> L.	Bud bloom	Herb	17	10	20	20	0
34	<i>Euphorbia heterophylla</i> L.	Bud bloom	Herb	13	13	7	20	0
35	<i>Festuca arundinacea</i> Schreb.	Bud bloom	Grass	0	10	3	0	7
36	<i>Glyceria maxima</i> (Hartm.) Holmb	Bud bloom	Grass	10	0	0	1	0
37	<i>Ghomphrena Celosioides</i> Mart.	Flowering	Herb	7	20	20	13	7
38	<i>Hyptis suaveolens</i> (L.) Poit.	Bud bloom	Herb	2	3	0	0	0
39	<i>Imperata cylindrica</i> (L.) Raeusch.	Bud bloom	Grass	7	13	10	3	20

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40	<i>Ipomea involucrate</i> P. Beauv.	Bud bloom	Herb	13	18	10	13	10
41	<i>Kylinga brevifolia</i> Rottb.	Fruiting	Sedge	0	3	3	0	0
42	<i>Laportea aestuans</i> (L.) Chew.	Bud bloom	Herb	20	3	17	0	0
43	<i>Laportea ovalifolia</i> (Schumach. & Thonn.) Chew.	Bud bloom	Herb	0	0	3	10	20
44	<i>Luffa cylindrica</i> (L.) Roem.	Fruiting	Climber	7	10	7	13	0
45	<i>Ludwigia octovalvis</i> (Jacq.) P.H. Raven	Bud bloom	Herb	0	3	17	0	0
46	<i>Lepochloa filiformis</i> (Pers.) P. Beauv.	Bud bloom	Grass	0	0	3	4	0
47	<i>Megathyrsus maximus</i> (Jack.) B. K. Simon & S.W.L. Jacobs	Bud bloom	Grass	0	0	10	0	0
48	<i>Momordica charantia</i> L.	Bud bloom	Climber	0	0	7	0	0
49	<i>Mimosa pudica</i> L.	Flowering	Herb	0	7	7	20	0
50	<i>Murdania nodiflora</i> (L.) Brenan	Bud bloom	Grass	0	0	13	1	0
51	<i>Melinis minutiflora</i> P. Beauv.	Flowering	Grass	0	10	7	0	7
52	<i>Ocimum canum</i> Sims.	Bud bloom	Herb	3	0	0	0	0
53	<i>Physalis angulata</i> L.	Fruiting	Herb	20	17	10	3	0
54	<i>Panicum repens</i> L.	Flowering	Grass	0	0	0	3	0
55	<i>Pennisetum purpureum</i> Schum	Bud bloom	Grass	0	10	0	7	17
56	<i>Portulaca oleracea</i> L.	Bud bloom	Herb	20	0	0	0	0
57	<i>Phyllanthus niruri</i> L.	Flowering	Herb	3	0	3	3	0
58	<i>Phyllanthus amarus</i> Schumach. & Thonn.	Bud bloom	Herb	0	0	0	0	7
59	<i>Psidium guajava</i> L.	Bud bloom	Short Tree	0	0	3	0	0
60	<i>Rumex crispus</i> L.	Flowering	Herb	0	0	3	13	0
61	<i>Rumex acetosella</i> L.	Bud bloom	Herb	3	0	0	10	17
62	<i>Sida acuta</i> Burm. F.	Flowering	Herb	13	3	7	0	20
63	<i>Sida rhombifolia</i> L.	Bud bloom	Herb	0	0	0	1	20
64	<i>Senna obtusifolia</i> (L.) Irwin & Barneby.	Bud bloom	Herb	7	0	0	2	0
65	<i>Spigelia anthelmia</i> L.	Bud bloom	Herb	3	0	0	2	0
66	<i>Solanum lycopersicum</i> L.	Bud bloom	Herb	3	0	0	0	0
67	<i>Solanum nigrum</i> L.	Bud bloom	Herb	0	3	4	7	0
68	<i>Synedrella nodiflora</i> (L.) Gaertn.	Bud bloom	Grass	3	7	0	3	0
69	<i>Setaria faberi</i> R.A.W. Herrm.	Bud bloom	Grass	7	0	0	1	7
70	<i>Sporobolus natalensis</i> (Steud.) Th. Dur. & Schinz	Bud bloom	Herb	0	7	0	1	0
71	<i>Sporobolus pyramidalis</i> P. Beauv.	Bud bloom	Grass	0	0	7	1	0
72	<i>Solenostemon Monostachyus</i> (P Beauv.) Briq.	Bud bloom	Herb	10	3	3	7	0
73	<i>Stachytarpheta jamaicensis</i> (L.) Vahl.	Bud bloom	Herb	3	0	0	0	0
74	<i>Trianthema portulacastrum</i> L.	Bud bloom	Herb	13	10	0	10	0
75	<i>Talinum triangulare</i> (Jacq.) Willd	Flowering	Herb	3	0	0	3	0
76	<i>Urena lobata</i> L.	Bud bloom	Shrub	10	3	7	0	0
77	<i>Vernonia cinerea</i> (L.) Less.	Flowering	Herb	0	7	0	10	0
78	<i>Veronica filiformis</i> Sm.	Bud bloom	Herb	0	0	0	0	3
79	<i>Zea mays</i> L.	Bud bloom	Herb	0	3	0	0	0

Table 3 – Showing percental value of relative frequency, density, relative dominance and important value indices for station A, B, C, D and E

S/N	Species	Family	Common Name	Relative Frequency (%)					Relative Density (Plants/m ²)					Total RD (%)					IVI
				A	B	C	D	E	Total RF(%)	A	B	C	D	E	Total RD (%)				
1	<i>Acalypha indica</i> L.	Euphorbiaceae	Copperleaf	0.00 ^a	0.00 ^a	1.89 ^{ab}	2.84 ^b	4.73	9.47	0.74 ^a	0.00 ^a	1.48 ^{ab}	2.22 ^b	3.70	8.15	11.99	29.6		
2	<i>Acalypha wilkesiana</i> Mull.Arg	Euphorbiaceae	Jacob's coat	0.00 ^a	0.00 ^a	0.00 ^{ab}	0.95 ^a	1.89	2.84	0.00 ^a	0.00 ^a	0.00 ^{ab}	0.74 ^a	1.48	2.22	3.60	8.66		
3	<i>Ambrosia artemisiifolia</i> L.	Asteraceae	Annual ragweed	1.89 ^a	0.00 ^a	0.57 ^{ab}	0.00 ^a	1.89	4.36	1.48 ^a	0.00 ^a	0.44 ^{ab}	0.00 ^a	1.48	3.41	5.51	13.28		
4	<i>Amaranthus spinosus</i> L.	Amaranthaceae	Thorny amaranth	2.84 ^a	3.79 ^a	2.84 ^{ab}	2.84 ^b	5.68	17.99	2.22 ^a	2.96 ^a	2.22 ^b	2.22 ^b	4.44	14.07	22.78	54.84		
5	<i>Amaranthus hybridus</i> L.	Amaranthaceae	Smooth pigweed	0.00 ^a	0.00 ^a	0.00 ^{ab}	1.89 ^a	0.00	1.89	0.00 ^a	0.00 ^a	0.00 ^{ab}	1.48 ^a	0.00	1.48	2.40	5.77		
6	<i>Aspilia Africana</i> (Pers.) C.D. Adams	Asteraceae	Haemorrhag e plant	3.79 ^a	0.00 ^a	0.57 ^{ab}	5.68 ^a	1.89	11.93	2.96 ^a	0.00 ^a	0.44 ^{ab}	4.44 ^a	1.48	9.33	15.10	36.37		
7	<i>Aspilia thouarsii</i> DC.	Asteraceae	Wild-sunflower	0.00 ^a	0.00 ^a	0.00 ^{ab}	2.84 ^b	0.00	2.84	0.00 ^a	0.00 ^a	0.00 ^{ab}	2.22 ^b	0.00	2.22	3.60	8.66		
8	<i>Ageratum conyzoides</i> L.	Asteraceae	Goat weed	3.79 ^a	1.89 ^a	4.73 ^{ab}	5.68 ^a	2.84	18.94	2.96 ^a	1.48 ^a	3.70 ^{ab}	4.44 ^a	2.22	14.81	23.97	57.73		
9	<i>Aeschynomene indica</i> L.	Fabaceae	Indian Joint vetch	0.00 ^a	0.95 ^a	0.95 ^a	0.00 ^a	0.00	1.89	0.00 ^a	0.74 ^a	0.74 ^a	0.00 ^a	0.00	1.48	2.40	5.77		
10	<i>Byrsocarpus coccineus</i> Schum. & Thonn.	Connaraceae	Hunt's man pepper	0.95 ^a	0.00 ^a	0.28 ^{ab}	0.00 ^a	0.00	1.23	0.74 ^a	0.00 ^a	0.22 ^{ab}	0.00 ^a	0.00	0.96	1.56	3.75		
11	<i>Cyathulla prostrata</i> (L.) Blume	Amaranthaceae	Pasture weed	0.95 ^a	0.00 ^a	0.00 ^{ab}	0.85 ^a	0.00	1.8	0.74 ^a	0.00 ^a	0.00 ^{ab}	0.67 ^a	0.00	1.41	2.28	5.48		
12	<i>Corchorus olitorius</i> L.	Malvaceae	Jute leaf	2.84 ^a	0.00 ^a	0.00 ^{ab}	0.00 ^a	0.00	2.84	2.22 ^a	0.00 ^a	0.00 ^{ab}	0.00 ^a	0.00	2.22	3.60	8.66		
13	<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob	Asteraceae	Elizabeth weed	1.89 ^a	0.00 ^a	0.95 ^a	0.00 ^a	0.95	3.79	1.48 ^a	0.00 ^a	0.74 ^a	0.00 ^a	0.74	2.96	4.79	11.55		
14	<i>Chloris barbata</i> Sw.	Poaceae	Finger grass	0.00 ^a	0.00 ^a	0.95 ^a	0.95 ^a	0.00	1.89	0.00 ^a	0.00 ^a	0.74 ^a	0.74 ^a	0.00	1.48	2.40	5.77		
15	<i>Commelina communis</i> L.	Commelinaceae	Asiatic day flower	0.00 ^a	1.89 ^a	0.00 ^{ab}	0.95 ^a	0.95	3.79	0.00 ^a	1.48 ^a	0.00 ^{ab}	0.74 ^a	0.74	2.96	4.79	11.55		
16	<i>Commelina diffusa</i> Burm.f.	Commelinaceae	Spreading day flower	2.84 ^a	1.89 ^a	0.95 ^a	1.89 ^a	0.00	7.58	2.22 ^a	1.48 ^a	0.74 ^a	1.48 ^a	0.00	5.93	9.59	23.09		
17	<i>Cyanotis axillaris</i> (L.) D. Don ex Sweet	Commelinaceae	Famine foods	0.00 ^a	0.95 ^a	0.00 ^{ab}	1.89 ^a	0.00	2.84	0.00 ^a	0.74 ^a	0.00 ^{ab}	1.48 ^a	0.00	2.22	3.60	8.66		

Table 3 – continued

18	<i>Cyperus deformis</i> L.	Cyperaceae	flat sedge	0.00 ^a	0.95 ^a	0.95 ^a	0.00 ^a	0.00	1.89	0.00 ^a	0.74 ^a	0.74 ^a	0.00 ^a	0.00	1.48	2.40	5.77
19	<i>Cyperus tenuispica</i> Steud.	Cyperaceae	Slender spiked sedge	0.00 ^a	2.84 ^a	3.79 ^{ab}	3.79 ^a	0.00	10.42	0.00 ^a	2.22 ^a	2.96 ^{ab}	2.96 ^a	0.00	8.15	13.19	31.75
20	<i>Cyperus iria</i> L.	Cyperaceae	Rice flat sedge	0.95 ^a	1.89 ^a	0.00 ^{ab}	0.00 ^a	0.00	2.84	0.74 ^a	1.48 ^a	0.00 ^{ab}	0.00 ^a	0.00	2.22	3.60	8.66
21	<i>Cyperus rotundus</i> L.	Cyperaceae	Nutgrass	0.00 ^a	0.00 ^a	3.79 ^{ab}	0.00 ^a	0.00	3.79	0.00 ^a	0.00 ^a	2.96 ^{ab}	0.00 ^a	0.00	2.96	4.79	11.55
22	<i>Cyperus compressus</i> L.	Cyperaceae	Annual sedge	0.00 ^a	0.95 ^a	0.00 ^{ab}	1.89 ^a	0.00	2.84	0.00 ^a	0.74 ^a	0.00 ^{ab}	1.48 ^a	0.00	2.22	3.60	8.66
23	<i>Cyperus esculentus</i> L.	Cyperaceae	Earth almond	1.89 ^a	0.00 ^a	4.73 ^{ab}	0.00 ^a	0.00	6.63	1.48 ^a	0.00 ^a	3.70 ^{ab}	0.00 ^a	0.00	5.19	8.39	20.2
24	<i>Cleome viscosa</i> L.	Cleomaceae	Asian spider flower	0.00 ^a	0.00 ^a	1.89 ^{ab}	0.95 ^a	4.73	7.58	0.00 ^a	0.00 ^a	1.48 ^{ab}	0.74 ^a	3.70	5.93	9.59	23.09
25	<i>Cleome rutidosperma</i> DC.	Cleomaceae	Fringed spider flower	0.00 ^a	1.89 ^a	0.95 ^a	0.95 ^a	0.00	3.79	0.00 ^a	1.48 ^a	0.74 ^a	0.74 ^a	0.00	2.96	4.79	11.55
26	<i>Calopogonium mucunoides</i> Desv.	Fabaceae	Wild groundnut	1.89 ^a	1.89 ^a	1.89 ^{ab}	2.84 ^b	5.68	14.2	1.48 ^a	1.48 ^a	1.48 ^{ab}	2.22 ^b	4.44	11.11	17.98	43.3
27	<i>Centrosema pubescens</i> Benth.	Fabaceae	Butterfly pea	0.00 ^a	0.95 ^a	0.00 ^{ab}	1.89 ^a	0.00	2.84	0.00 ^a	0.74 ^a	0.00 ^{ab}	1.48 ^a	0.00	2.22	3.60	8.66
28	<i>Digitaria sanguinalis</i> (L.) Scop.	Poaceae	Hairy crab grass	0.00 ^a	0.00 ^a	0.28 ^{ab}	2.84 ^b	2.84	5.97	0.00 ^a	0.00 ^a	0.22 ^{ab}	2.22 ^b	2.22	4.67	7.55	18.18
29	<i>Emilia coccinea</i> (Sims.) G. Don.	Asteraceae	Scarlet tassel flower	0.00 ^a	0.00 ^a	0.00 ^{ab}	2.84 ^b	0.00	2.84	0.00 ^a	0.00 ^a	0.00 ^{ab}	2.22 ^b	0.00	2.22	3.60	8.66
30	<i>Echinochloa crus-galli</i> (L.) P. Beauv.	Poaceae	Cockspur grass	0.95 ^a	2.84 ^a	0.95 ^a	5.68 ^a	0.00	10.42	0.74 ^a	2.22	0.74 ^a	4.44 ^a	0.00	8.15	13.19	31.75
31	<i>Echinochloa colonum</i> (L.) Link.	Poaceae	Jungle rice	3.79 ^a	1.89 ^a	0.00 ^{ab}	2.84 ^b	0.95	9.47	2.96 ^a	1.48 ^a	0.00 ^{ab}	2.22 ^b	0.74	7.41	11.99	28.86
32	<i>Eleusine indica</i> (L.) Gaertn.	Poaceae	Indian goosegrass	4.73 ^a	5.68 ^a	5.68 ^{ab}	0.95 ^a	0.00	17.05	3.70 ^a	4.44 ^a	4.44 ^{ab}	0.74 ^a	0.00	13.33	21.58	51.96
33	<i>Euphorbia hirta</i> L.	Euphorbiaceae	Asthma weed	4.73 ^a	2.84 ^a	5.68 ^{ab}	5.68 ^a	0.00	18.94	3.70 ^a	2.22 ^a	4.44 ^{ab}	4.44 ^a	0.00	14.81	23.97	57.73
34	<i>Euphorbia heterophylla</i> L.	Euphorbiaceae	milkweed	3.79 ^a	3.79 ^a	1.89 ^{ab}	5.68 ^a	0.00	15.15	2.96 ^a	2.96 ^a	1.48 ^{ab}	4.44 ^a	0.00	11.85	19.18	46.18
35	<i>Festuca arundinacea</i> Schreb.	Poaceae	Tall fescue	0.00 ^a	2.84 ^a	0.95 ^a	0.00 ^a	1.89	5.68	0.00 ^a	2.22 ^a	0.74 ^a	0.00 ^a	1.48	4.44	7.19	17.32
36	<i>Glyceria maxima</i> (Hartm.) Holmb	Poaceae	Reed manna grass	2.84 ^a	0.00 ^a	0.00 ^{ab}	0.28 ^a	0.00	3.13	2.22 ^a	0.00 ^a	0.00 ^{ab}	0.22 ^a	0.00	2.44	3.96	9.53

Table 3 – continued

37	<i>Ghomphrena celosoides</i> Mart.	Amaranthaceae	Bachelor's button	1.89 ^a	5.68 ^a	5.68 ^{ab}	3.79 ^a	1.89	23.44	1.48 ^a	4.44 ^a	4.44 ^{ab}	2.96 ^a	1.48 ^a	14.81	29.67	57.73
38	<i>Hyptis suaveolens</i> (L.) Poit.	Lamiaceae	American mint	0.57 ^a	0.95 ^a	0.00 ^{ab}	0.00 ^a	0.00	1.52	0.44 ^a	0.74 ^a	0.00 ^{ab}	0.00 ^a	0.00	1.19	1.92	4.62
39	<i>Imperata cylindrica</i> (L.) Raeusch.	Poaceae	Cogon grass	1.89 ^a	3.79 ^a	2.84 ^b	0.95 ^a	5.68	15.15	1.48 ^a	2.96 ^a	2.22 ^b	0.74 ^a	4.44	11.85	19.18	46.18
40	<i>Ipomea involucreata</i> P.Beauv.	Convolvulaceae	Morning glory	3.79 ^a	5.11 ^a	2.84 ^b	3.79 ^a	2.84	18.37	2.96 ^a	4.00 ^a	2.22 ^b	2.96 ^a	2.22	14.37	23.25	56.00
41	<i>Kyllinga brevifolia</i> Rottb.	Cyperaceae	Shortleaf spikesedge	0.00 ^a	0.95 ^a	0.95 ^a	0.00 ^a	0.00	1.89	0.00 ^a	0.74 ^a	0.74 ^a	0.00 ^a	0.00	1.48	2.40	5.77
42	<i>Laportea aestuans</i> (L.) Chew.	Urticaceae	West Indian wood nettle	5.68 ^a	0.95 ^a	4.73 ^{ab}	0.00 ^a	0.00	11.36	4.44 ^a	0.74 ^a	3.70 ^{ab}	0.00 ^a	0.00	8.89	14.38	34.64
43	<i>Laportea ovalifolia</i> (Schumach. & Thonn.) Chew.	Urticaceae	Dandy	0.00 ^a	0.00 ^a	0.95 ^a	2.84 ^b	5.68	9.47	0.00 ^a	0.00 ^a	0.74 ^a	2.22 ^b	4.44	7.41	11.99	28.86
44	<i>Luffa cylindrica</i> (L.) Roem.	Cucurbitaceae	Sponge gourd	1.89 ^a	2.84 ^a	1.89 ^{ab}	3.79 ^a	0.00	10.42	1.48 ^a	2.22 ^a	1.48 ^{ab}	2.96 ^a	0.00	8.15	13.19	31.75
45	<i>Ludwigia octovalvis</i> (Jacq.) P.H. Raven	Onagraceae	Mexican prime rose-willow	0.00 ^a	0.95 ^a	4.73 ^{ab}	0.00 ^a	0.00	5.68	0.00 ^a	0.74 ^a	3.70 ^{ab}	0.00 ^a	0.00	4.44	7.19	17.32
46	<i>Lepochloa filiformis</i> (Pers.) P. Beauv.	Poaceae	Red sprangle top	0.00 ^a	0.00 ^a	0.95 ^a	1.14 ^a	0.00	2.08	0.00 ^a	0.00 ^a	0.74 ^a	0.89 ^a	0.00	1.63	2.64	6.35
47	<i>Maximus</i> (Jack.) B. K. Simon & S.W.L. Jacobs	Poaceae	Guinea grass	0.00 ^a	0.00 ^a	2.84 ^b	0.00 ^a	0.00	2.84	0.00 ^a	0.00 ^a	2.22 ^b	0.00 ^a	0.00	2.22	3.60	8.66
48	<i>Momordica charantia</i> L.	Cucurbitaceae	Bitter melon	0.00 ^a	0.00 ^a	1.89 ^{ab}	0.00 ^a	0.00	1.89	0.00 ^a	0.00 ^a	1.48 ^{ab}	0.00 ^a	0.00	1.48	2.40	5.77
49	<i>Mimosa pudica</i> L.	Fabaceae	Sensitive plant	0.00 ^a	1.89 ^a	1.89 ^{ab}	5.68 ^a	0.00	9.47	0.00 ^a	1.48 ^a	1.48 ^{ab}	4.44 ^a	0.00	7.41	11.99	28.86
50	<i>Murdannia nodiflora</i> (L.) Brenan	Commelinaceae	Dove weed	0.00 ^a	0.00 ^a	3.79 ^{ab}	0.28 ^a	0.00	4.07	0.00 ^a	0.00 ^a	2.96 ^{ab}	0.22 ^a	0.00	3.19	5.15	12.41
51	<i>Melinis minutiflora</i> P. Beauv.	Poaceae	Molasses grass	0.00 ^a	2.84 ^a	1.89 ^{ab}	0.00 ^a	1.89	6.63	0.00 ^a	2.22 ^a	1.48 ^{ab}	0.00 ^a	1.48 ^a	5.19	8.39	20.20
52	<i>Ocimum canum</i> Sims.	Lamiaceae	Wild basil	0.95 ^a	0.00 ^a	0.00 ^{ab}	0.00 ^a	0.00	0.95	0.74 ^a	0.00 ^a	0.00 ^{ab}	0.00 ^a	0.00	0.74	1.20	2.89

Table 3 – continued

53	<i>Physalis angulata</i> L.	Solanaceae	Cut-leaved-ground-cherry	5.68 ^a	4.73 ^a	2.84 ^b	0.95 ^a	0.00	14.2	4.44 ^a	3.70 ^a	2.22 ^b	0.74 ^a	0.00	11.11	17.98	43.30
54	<i>Panicum repens</i> L.	Poaceae	Torpedo grass	0.00 ^a	0.00 ^a	0.00 ^{ab}	0.95 ^a	0.00	0.95	0.00 ^a	0.00 ^a	0.00 ^{ab}	0.74 ^a	0.00	0.74	1.20	2.89
55	<i>Pennisetum purpureum</i> Schum	Poaceae	Elephant grass	0.00 ^a	2.84 ^a	0.00 ^{ab}	1.89 ^a	4.73	9.47	0.00 ^a	2.22 ^a	0.00 ^{ab}	1.48 ^a	3.70 ^{ab}	7.41	11.99	28.86
56	<i>Portulaca oleracea</i> L.	Portulacaceae	Common-purslane	5.68 ^a	0.00 ^a	0.00 ^{ab}	0.00 ^a	0.00	5.68	4.44 ^a	0.00 ^a	0.00 ^{ab}	0.00 ^a	0.00	4.44	7.19	17.32
57	<i>Phyllanthus niruri</i> L.	Phyllanthaceae	Gale of the wind	0.95 ^a	0.00 ^a	0.95 ^a	0.95 ^a	0.00	2.84	0.74 ^a	0.00 ^a	0.74 ^a	0.74 ^a	0.00	2.22	3.60	8.66
58	<i>Phyllanthus amarus</i> Schumacher. & Thonn.	Phyllanthaceae	Stone breaker	0.00 ^a	0.00 ^a	0.00 ^{ab}	0.00 ^a	1.89	1.89	0.00 ^a	0.00 ^a	0.00 ^{ab}	0.00 ^a	1.48 ^a	1.48	2.40	5.77
59	<i>Psidium guajava</i> L.	Myrtaceae	Common guava	0.00 ^a	0.00 ^a	0.95 ^a	0.00 ^a	0.00	0.95	0.00 ^a	0.00 ^a	0.74 ^a	0.00 ^a	0.00	0.74	1.20	2.89
60	<i>Rumex crispus</i> L.	Polygonaceae	Cury dock or yellow dock	0.00 ^a	0.00 ^a	0.95 ^a	3.79 ^a	0.00	4.73	0.00 ^a	0.00 ^a	0.74 ^a	2.96 ^a	0.00	3.70	5.99	14.43
61	<i>Rumex acetosella</i> L.	Polygonaceae	Sheep's sorrel	0.95 ^a	0.00 ^a	0.00 ^{ab}	2.84 ^b	4.73	8.52	0.74 ^a	0.00 ^a	0.00 ^{ab}	2.22 ^b	3.70 ^{ab}	6.67	10.79	25.98
62	<i>Sida acuta</i> Burm. F.	Malvaceae	Common wire weed	3.79 ^a	0.95 ^a	1.89 ^{ab}	0.00 ^a	5.68	12.31	2.96 ^a	0.74 ^a	1.48 ^{ab}	0.00 ^a	4.44 ^a	9.63	15.58	37.52
63	<i>Sida rhombifolia</i> L.	Malvaceae	Arrow leaf weed	0.00 ^a	0.00 ^a	0.00 ^{ab}	0.28 ^a	5.68	5.97	0.00 ^a	0.00 ^a	0.00 ^{ab}	0.22 ^a	4.44 ^a	4.67	7.55	18.18
64	<i>Senna obtusifolia</i> (L.) Irwin & Barneby.	Fabaceae	Sickle pod	1.89 ^a	0.00 ^a	0.00 ^{ab}	0.57 ^a	0.00	2.46	1.48 ^a	0.00 ^a	0.00 ^{ab}	0.44 ^a	0.00	1.93	3.12	7.50
65	<i>Spigelia anthelmia</i> L.	Loganiaceae	West Indian pinkroot	0.95 ^a	0.00 ^a	0.00 ^{ab}	0.57 ^a	0.00	1.52	0.74 ^a	0.00 ^a	0.00 ^{ab}	0.44 ^a	0.00	1.19	1.92	4.62
66	<i>Solanum lycopersicum</i> L.	Solanaceae	Tomato	0.95 ^a	0.00 ^a	0.00 ^{ab}	0.00 ^a	0.00	0.95	0.74 ^a	0.00 ^a	0.00 ^{ab}	0.00 ^a	0.00	0.74	1.20	2.89
67	<i>Solanum nigrum</i> L.	Solanaceae	European black head night shade	0.00 ^a	0.95 ^a	1.14 ^{ab}	1.89 ^a	0.00	3.98	0.00 ^a	0.74 ^a	0.89 ^{ab}	1.48 ^a	0.00	3.11	5.03	12.12
68	<i>Synedrella nodiflora</i> (L.) Gaertn.	Asteraceae	Cinderella weed	0.95 ^a	1.89 ^a	0.00 ^{ab}	0.95 ^a	0.00	3.79	0.74 ^a	1.48 ^a	0.00 ^{ab}	0.74 ^a	0.00	2.96	4.79	11.55

Table 6 shows the dry biomass content, total carbon content and sequestered carbon dioxide estimate at stations A, B, C, D and E. The sequestered carbon dioxide estimation was highest in the following families: Solanaceae at station A (15.15 g/m²), Aizoceae at station B (5.59 g/m²), Poaceae at station C (4.22 g/m²), Commelineaceae at station D (9.86 g/m²) and Fabaceae at station E (35.35 g/m²). Comparatively, the carbon evaluation showed that Fabaceae species sequestered the most carbon across all study stations. *Table 7* and *Table 8* show the ANOVA for TSC and SCO₂E. The analysis revealed that only the dormant dumpsites (Newlayout and FETHA) showed a significant difference at $p < 0.05$.

The data utilised for the analysis were the mean data of the total family of species encountered. The total number of families considered was 25. The TSC was not significant at station A (Waterworks) ($F=0.64$ and $p=0.78$) or B (Kpirikpiri) ($F=0.211$ and $p=0.10$).

However, at dormant stations C (Newlayout: $F=15.97$ and $p < 0.001$) and D (FETHA: $F=43.68$ and $p < 0.001$), the results obtained were significantly different at $p < 0.05$. In addition, the SCO₂E evaluated at active dump stations A and B did not show a significant difference ($p > 0.05$). In contrast, dormant stations C ($F=15.97$ and $p < 0.001$) and D ($F=43.68$, $p < 0.001$) were significantly different at $p < 0.05$.

Station A (waterworks dumpsite)

The rich species diversity and distribution at station A are were to age, amount of litter deposition, duration of decomposition and plant–soil

interactions. Other factors associated with the improvement of plant diversity included the presence of nitrogen-fixing legumes, plant leaflet area, soil composition and structure, and topography, which play important roles in the formation of ecology, diversity and abundance of species at dump grounds. The TSC and SCO₂E evaluated indicate that species in the Solanaceae family (*Physalis angulata*) were good carbon sinks and could be used for phytoremediation.

Station B (Kpirikpiri dumpsite)

This dumpsite was relatively young compared to the other sites evaluated. Wastes generated were composed primarily of biodegradable materials from the Kpirikpiri market and its residential environs.

The composition of waste deposits, soil type and age of dumpsite accounted for the high percentage of species composition and abundance at the site. The rich soil properties were associated with plants and soil interactions with microbes. The dumpsite had fertile soil and supported agricultural activities, such as subsistence farming.

The TSC and SCO₂E showed that the Aizoceae family (*Trianthema portulacastrum*) sequestered the most carbon dioxide at this location.

Station C (Newlayout dumpsite)

Soils at the abandoned or dormant study location C had a high proportion of sand, suggesting that the site is prone to leachate seepage. The percental soil composition, leachate seepage and age of dumps were most likely to have contributed to plant diversity.

Table 4 – Showing Duncans multiple range test for relative frequency of distributionand relative density in study station A, B, C, D and E

Parameter	Study location /Dumpsite	Original order of mean	Ranked mean	LSD value	P (at alpha)	Standard deviation	Number of species considered
Relative frequency	A	0.95 ^a	0.95 ^a	0.95	0.05	1.64	79
	B	2.84 ^{ab}	2.84 ^{ab}			1.48	
	C	1.89 ^{ab}	1.89 ^{ab}			1.6	
	D	4.73 ^{ab}	4.73 ^{ab}			1.71	
	E	5.68 ^{ab}	5.68 ^{ab}			1.82	
Relative density	A	0.74 ^a	0.74 ^a	0.74	0.05	1.28	79
	B	2.22 ^a	2.22 ^a			1.16	
	C	1.48 ^{ab}	1.48 ^{ab}			1.25	
	D	3.70 ^{ab}	3.70 ^{ab}			1.33	
	E	4.44 ^a	4.44 ^a			1.42	

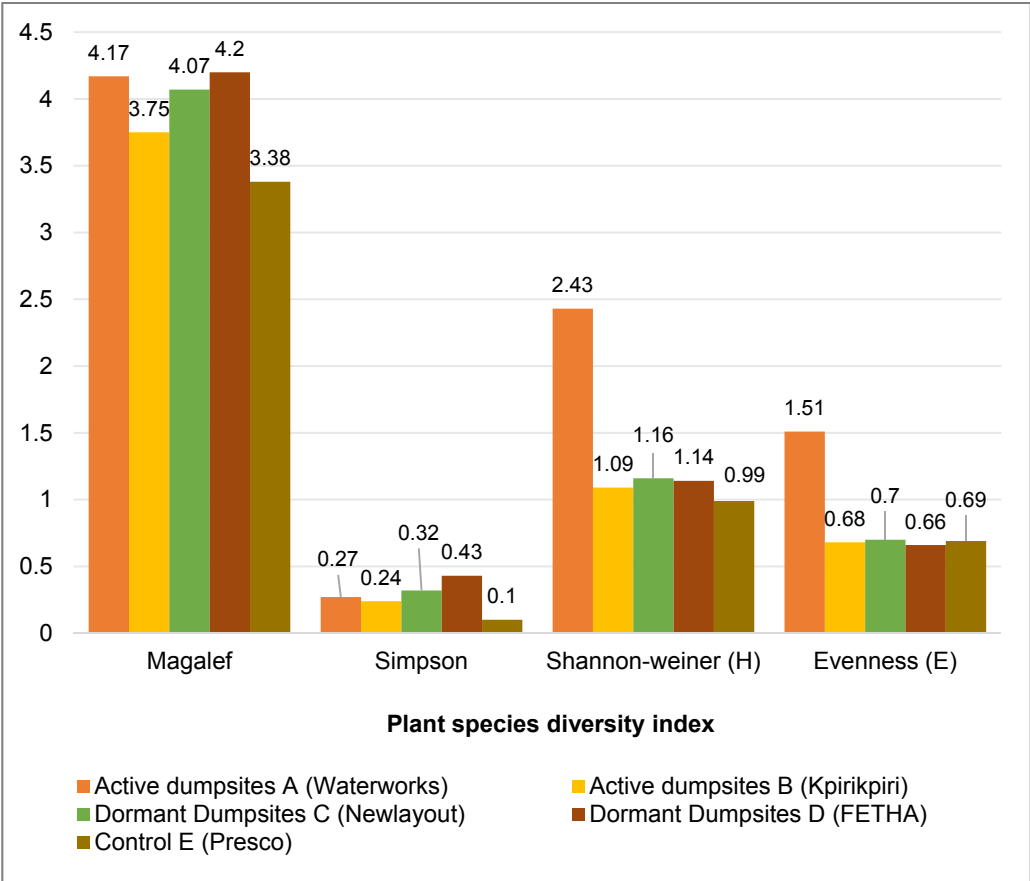


Figure 2 – Showing Margalef species richness, Simpson’s species dominance, Shannon-weiner diversity and Pileou’s evenness indices in stations A, B, C, D and E

Table 5 – Analysis of variance for relative frequency and relative density in stations A, B, C, D

Parameter	Study Location /Dumpsite	Sum of Squares	df	Mean Square	F	Sig.	N	Decision at 0.05	
Relative frequency	Waterworks (A)	Between Groups	10.67	5	2.13	0.78	0.57	79	Not significant
		Within Groups	198.91	73	2.73				
		Total	209.59	78					
	Kpirikpiiri (B)	Between Groups	8.99	5	1.80	0.81	0.55	79	Not significant
		Within Groups	162.45	73	2.23				
		Total	171.43	78					
	Newlayout (C)	Between Groups	11.51	5	2.30	0.89	0.49	79	Not significant
		Within Groups	188.04	73	2.58				
		Total	199.54	78					
	FETHA (D)	Between Groups	25.37	5	5.07	1.83	0.12	79	Not significant
		Within Groups	202.14	73	2.77				
		Total	227.51	78					
Relative density	Waterworks (A)	Between Groups	5.47	5	1.09	0.66	0.66	79	Not significant
		Within Groups	121.69	73	1.67				
		Total	127.16	78					
	Kpirikpiri (B)	Between Groups	5.50	5	1.10	0.81	0.55	79	Not significant
		Within Groups	99.31	73	1.36				
		Total	104.81	78					
	Newlayout (C)	Between Groups	7.04	5	1.41	0.90	0.49	79	Not significant
		Within Groups	114.97	73	1.58				
		Total	122.01	78					
	FETHA (D)	Between Groups	15.50	5	3.10	1.83	0.12	79	Not significant
		Within Groups	123.51	73	1.69				
	Total		139.007	78					

The TSC and SCO₂E showed that *Eleusine indica* was the most important grass species. Members of the Poaceae family were abundant and sequestered the most carbon dioxide. They are recommended for the restoration of degraded lands.

Station D (FETHA)

The abandoned dumpsite had the highest species richness and dominance and was ranked second and fifth in terms of location with the most diverse and

evenly distributed species, respectively. Species richness and dominance may be associated with the influence of pollination agents during seed dispersal. Species composition and abundance were moderate compared to other study locations.

The FETHA dump was ranked fourth in terms of species richness, dominance, diversity and evenness values obtained across dumpsites.

Table 6 – Showing Families encountered, Dry Biomass content, Total Carbon Content and Sequestered Carbon Estimate in stations A, B, C, D and E

Family	Oven Dry Biomass Content (g/m ²)					Total Sequestered Carbon (TSC) (g/m ²)					Sequestered Carbon dioxide Estimate (SCO ₂ E) (g/m ²)				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Aizoceae	0.00±	3.20±	0.00±	0.54±	0±0.3	0.29±	1.52±	0.00±	0.26±	0.00±	0.00±	5.59±	0.00±	0.95±	0.00±
	0.56	4.06	0.62	0.16	3	0.30	4.06	0.62	0.16	0.33	0.56	4.07	0.62	0.16	0.33
Amaranthaceae	0.45±	0.55±	1.43±	1.46±	0.23±	0.21±	0.26±	0.68±	0.69±	0.11±	0.79±	0.97±	2.51±	2.5s±0	0.39±
	0.35	0.18	1.48	0.58	0.22	0.37	1.18	1.47	0.58	0.28	0.35	0.18	1.48	.58	0.28
Asteraceae	0.49±	0.78±	0.10±	0.72±	0.77±	0.23±	0.37±	0.05±	0.34±	0.36±	0.86±	1.36±	0.18±	1.26±	1.34±
	0.33	0.51	0.47	0.02	0.15	0.34	0.51	0.47	0.02	0.15	0.33	0.51	0.48	0.02	0.15
Cleomaceae	0.00±	0.00±	0.14±	0.60±	0.00±	0.00±	0.00±	0.07±	0.29±	0.00±	0.00±	0.00±	0.25±	1.05±	0.00±
	0.56	0.63	0.41	0.12	0.33	0.57	0.63	0.41	0.12	0.33	0.56	0.63	0.41	0.12	0.33
Connaraceae	0.00±	0.18±	0.17±	0.17±	0.00±	0.00±	0.09±	0.08±	0.08±	0.00±	0.00±	0.32±	0.29±	0.29±	0.00±
	0.56	0.36	0.37	0.47	0.33	0.57	0.36	0.37	0.47	0.33	0.56	0.35	0.37	0.47	0.33
Convulvulaceae	2.28±	1.48±	0.21±	0.56±	0.67±	1.08±	0.70±	0.10±	0.27±	0.32±	3.97±	2.58±	0.36±	0.97±	1.16±
	0.48	1.53	0.32	0.15	0.17	0.47	1.54	0.32	0.15	0.17	0.48	1.54	0.32	0.15	0.17
Commelineaceae	1.88±	0.92±	1.26±	5.66±	2.12±	0.89±	0.44±	0.60±	2.69±	1.01±	3.28±	1.62±	2.19±	9.86±	3.70±
	0.30	0.73	1.22	3.99	0.17	0.29	0.73	1.21	3.99	1.17	0.30	0.73	1.21	3.99	0.17
Cucurbitaceae	0.59±	0.41±	0.22±	0.63±	0.00±	0.28±	0.20±	0.11±	0.30±	0.00±	1.03±	0.72±	0.39±	1.10±	0.00±
	0.29	0.02	0.29	0.09	0.33	0.30	0.02	0.29	0.09	0.33	0.29	0.02	0.29	0.09	0.33
Cyperaceae	0.44±	0.21±	0.13±	0.33±	0.00±	0.21±	0.10±	0.06±	0.16±	0.00±	0.77±	0.37±	0.23±	0.58±	0.00±
	0.35	0.31	0.43	0.34	0.33	0.37	0.31	0.43	0.34	0.33	0.36	0.31	0.43	0.34	0.33
Euphorbiaceae	0.77±	0.30±	0.11±	0.55±	0.11±	0.37±	0.14±	0.05±	0.26±	0.05±	1.35±	0.53±	0.19±	0.96±	0.20±
	0.21	0.18	0.46	0.16	0.30	0.22	18	0.46	0.16	0.30	0.21	0.18	0.46	0.16	0.30
Fabaceae	0.66±	0.46±	0.53±	0.18±	0.20±	0.32±	0.22±	0.25±	0.09±	9.63±	1.16±	0.80±	0.92±	0.32±	35.35
	0.26	0.04	0.15	0.46	±4.85	0.27	0.04	0.15	0.46	4.49	0.25	0.04	0.15	0.46	±4.49

Table 6 – continued

Lamiaceae	7.60± 2.89	0.17± 0.38	0.19± 0.35	0.24± 0.42	0.18± 0.29	3.61± 2.90	0.08± 0.38	0.09± 0.35	0.11± 0.42	0.08± 0.29	13.24 ±2.89	0.30± 0.38	0.32± 0.35	0.42± 0.42	0.31± 0.29
Loganiaceae	0.91± 0.15	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.00± 0.33	0.43± 0.15	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.00± 0.33	1.60± 0.14	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.00± 0.33
Malvaceae	0.68± 0.25	0.22± 0.30	0.21± 0.31	0.28± 0.37	7.23± 1.38	0.33± 0.26	0.11± 0.30	0.10± 0.32	0.14± 0.38	3.43± 1.38	1.19± 0.25	0.38± 0.30	0.37± 0.31	0.49± 0.38	12.60 ±1.38
Myrtaceae	0.00± 0.56	0.00± 0.63	0.147 ±0.40	0.00± 0.61	0.00± 0.33	0.00± 0.57	0.00± 0.63	0.07± 0.41	0.00± 0.61	0.00± 0.33	0.00± 0.56	0.00± 0.63	0.26± 0.40	0.00± 0.61	0.00± 0.33
Onagraceae	0.00± 0.56	0.39± 0.05	0.12± 0.44	0.00± 0.61	0.00± 0.33	0.00± 0.57	0.19± 0.05	0.06± 0.43	0.00± 0.61	0.00± 0.33	0.00± 0.56	0.69± 0.05	0.21± 0.44	0.00± 0.61	0.00± 0.33
Plantaginaceae	0.00± 0.56	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.12± 0.30	0.00± 0.57	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.06± 0.30	0.00± 0.56	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.20± 0.30
Portulacaceae	0.88± 0.16	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.00± 0.33	0.42± 0.17	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.00± 0.33	1.53± 0.16	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.00± 0.33
Phyllanthaceae	0.04± 0.54	0.00± 0.63	0.04± 0.56	0.07± 0.55	0.03± 0.32	0.02± 0.55	0.00± 0.63	0.02± 0.56	0.03± 0.55	0.01± 0.32	0.07± 0.54	0.00± 0.63	0.07± 0.56	0.12± 0.55	0.05± 0.32
Polygonaceae	0.87± 0.16	0.00± 0.63	0.11± 0.45	1.79± 0.85	0.48± 0.23	0.41± 0.18	0.00± 0.63	0.05± 0.45	0.85± 0.85	0.23± 0.22	1.51± 0.16	0.00± 0.63	0.20± 0.45	3.13± 0.85	0.840. 22
Poaceae	0.62± 0.27	0.58± 0.22	2.42± 2.91	2.15± 1.14	0.56± 0.20	0.30± 0.29	0.27± 0.22	1.15± 2.91	1.02± 1.14	0.26± 0.19	1.09± 0.27	1.00± 0.22	4.22± 2.91	3.75± 1.14	0.97± 0.20
Solanaceae	8.69± 3.39	0.61± 0.27	0.82± 0.58	0.10± 0.52	0.00± 0.33	4.13± 3.40	0.29± 0.28	0.39± 0.58	0.05± 0.52	0.00± 0.33	15.15 ±3.39	1.06± 0.27	1.43± 0.58	0.18± 0.52	0.00± 0.33
Talinaceae	0.14± 0.49	0.00± 0.63	0.00± 0.62	0.23± 0.42	0.00± 0.33	0.07± 0.51	0.00± 0.63	0.00± 0.62	0.11± 0.42	0.00± 0.33	0.24± 0.50	0.00± 0.63	0.00± 0.62	0.41± 0.42	0.00± 0.33
Urticaceae	2.604 ±0.62	0.219 ±0.31	2.248 ±2.66	2.391 ±1.33	2.115 ±0.17	1.24± 0.62	0.10± 0.31	1.07± 2.66	1.14± 1.34	1.01± 1.17	4.54± 0.62	0.38± 0.31	3.92± 0.26	4.167 ±1.34	3.69± 0.17
Verbenaceae	0.12± 0.50	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.00± 0.33	0.06± 0.52	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.00± 0.33	0.21± 0.50	0.00± 0.63	0.00± 0.62	0.00± 0.61	0.00± 0.33

Table 7 – Showing analysis of variance (ANOVA) for Total Sequestered Carbon (TSC) and Sequestered Carbon dioxide Estimate (SCO₂E) in studied locations (A, B, C, D and D)

Parameter	Study location		Sum of Squares	df	Mean Square	F	Sig.	N	Decision at p< 0.05
Total Sequestered Carbon (TSC)	Waterworks (Active) A	Between Groups	152.26	13	11.712	0.641	0.779	25	Not significant
		Within Groups	201.07	11	18.279				
		Total	353.33	24					
	Kpirikpiri (Active) B	Between Groups	6.78	13	0.522	0.211	0.995	25	Not significant
		Within Groups	27.19	11	2.472				
		Total	33.97	24					
	Newlayout (Dormant) C	Between Groups	32.65	13	2.512	15.965	<.001	25	Significant
		Within Groups	1.73	11	0.157				
		Total	34.38	24					
	FETHA (Dormant) D	Between Groups	108.32	13	8.333	43.675	<.001	25	Significant
		Within Groups	2.1	11	0.191				
		Total	110.42	24					
Sequestered Carbon-dioxide Estimate (SCO ₂ E)	Waterworks (Active) A	Between Groups	50.1	13	3.854	0.641	0.78	25	Not significant
		Within Groups	66.17	11	6.015				
		Total	116.27	24					
	Kpirikpiri (Active) B	Between Groups	2.231	13	0.172	0.211	0.995	25	Not significant
		Within Groups	8.95	11	0.813				
		Total	11.18	24					
	Newlayout (Dormant) C	Between Groups	10.74	13	0.826	15.959	<.001	25	Significant
		Within Groups	0.57	11	0.052				
		Total	11.31	24					
	FETHA (Dormant) D	Between Groups	35.64	13	2.742	43.678	<.001	25	Significant
		Within Groups	0.69	11	0.063				
		Total	36.33	24					

Table 8 – showing the continuation of ANOVA for sequestered carbon and sequestered carbon-dioxide equivalent

Parameters	Study locations	Mean	Minimum mean	Maximum mean	P (at alpha)	Standard deviation	No. of families considered
Total Sequestered Carbon (TSC)	Waterworks (Active) A	0.6	0	15.15	0.05	1.04	25
	Kpirikpiri (Active) B	0.2	0	5.59		0.32	
	Newlayout (Dormant) C	0.2	0	4.22		0.33	
	FETHA (Dormant) D	0.35	0	9.86		0.32	
	Presco (Control) E	0.66	0	35.35		0.58	
Sequestered Carbon Equivalent (SCO ₂ E)	Waterworks (Active) A	2.14	0	15.15	0.05	3.84	25
	Kpirikpiri (Active) B	0.75	0	5.59		1.19	
	Newlayout (Dormant) C	0.74	0	4.22		1.2	
	FETHA (Dormant) D	1.3	0	9.86		2.14	
	Presco (Control) E	2.43	0	35.35		7.34	

The TSC and SCO₂E showed that species in the Commelinaceae family (*Murdinnia nodiflora*, *Commelina communis*, *Commelina diffusa* and *Cyanotis axillaris*) were the best carbon sink at this station and could be recommended as phytoremediators in polluted environments.

Station E (Presco)

Information on species richness, dominance, diversity and evenness were lowest at this station.

The spatial distribution and relatively low diversity were connected to the soil morphology, topography and influence of pollutants at the study area. The SCO₂E showed that the leguminous species *Calapogonum mucunoides* (Fabaceae) sequestered the most carbon not only in the control but also across all study locations evaluated.

DISCUSSION

Plants adopt several suitable defence mechanisms when exposed to certain environmental pollutants, especially from the soil. These adapted mechanisms assist in the prevention of alterations in the physiological and genetic makeup of plants in such ecosystems.

The process of preventing such alterations is associated with phytoremediation.

There are five principal phytoremediation strategies that plants employ during exposure to potentially toxic elements in ecosystems, such as open waste disposal sites (Wafaa, 2024).

The strategies include phytoextraction, phytodegradation or rhizo-degradation, rhizo-filtration, phyto-

stabilisation, and phyto-volatilisation. These strategies help stabilise and regulate pollutants in the soil.

The phytoextraction strategy involves the removal or storage of potentially toxic elements in different parts of the plant, leading to the increased production of plant biomass containing toxic elements that can be translocated for disposal in different aerial parts of the plant.

The increased biomass in species at the active dumpsites suggests the adoption of this kind of mechanism. The increased biomass in dump species is attributed to a metabolic process activated during plant interactions with toxins in the soil. According to recent findings, species in the Dogbanes family (Example: *Calotropis procera*) are known to exhibit this type of phytoremediation mechanism (Singh and Fulzele, 2021).

Another strategy activated during exposure to potentially toxic elements is phytodegradation or rhizo-degradation. This strategy is initiated during the degradation of toxic elements by enzymes in association with microbes in the soil. Species including *Phragmites australis* (Poaceae) have been reported to carry out this strategy (Gilbert *et al.*, 2017).

The third strategy is initiated by plants during pollutant bioaccumulation and is referred to as rhizo-filtration. This strategy mostly occurs in sedge species. *Carex pendula* has been reported to successfully carry out rhizo-filtration. In this case, potentially toxic elements are absorbed from the roots of the plant to aerial parts (Yan *et al.*, 2020).

The fourth strategy employed is phyto-stabilisation; during this process, potentially toxic elements are immobilised, leading to a reduction in bioavailability. An example is *Juncus effusus* (Thompson *et al.*, 2021). Phyto-volatilisation involves the metabolic process of extracting toxic elements from the soil to the atmosphere through plants. The phyto-volatilisation process has been reported in *Pteris vittata* in the Brake family (Pteridaceae), (Sliwa-Cebula, *et al.*, 2020).

In this work, species with high tolerance to potentially toxic elements were measured by evaluating the amount of carbon sequestration in each species and family.

Carbon is one of the most valued elements useful to plants, especially during respiration, decomposition, combustion and photosynthesis.

The anthropogenic activities of man, such as land use and waste disposal patterns, have caused a rapid increase in the atmospheric quantity of carbon greater than ever before. The results on abundance, frequency and diversity indices obtained present a research question as to reasons for species adaptation in both active and abandoned dumpsites, similar to the unpolluted environment.

To answer the research question, the evaluation of biomass content and carbon uptake was investigated. Invasive species found in the Solanaceae, Poaceae, Aizoaceae and Commelinaceae families served as the best carbon sequesters, suggesting a close affinity to phytoremediation strategies. This is because phytoextraction and bioaccumulation processes occur, which

tend to cause an increase in the biomass of species inhabiting the dump locations compared to the same species at the other locations evaluated.

Further findings on the different contamination levels responsible for carbon accumulation in dumpsite ecosystem plants and the evaluation of different phytoremediation mechanisms employed by plants are ongoing, and these data will be the concluding part of this investigation.

The richness in species diversity, abundance, composition and carbon storage quantity at the active dumpsites were mostly attributed to abiotic factors such as the presence of nitrogen-fixing legumes, age of the dumpsite, amount of litter deposition, duration of decomposition and plant–soil interactions (Schrish *et al.*, 2022).

The soil composition, climatic condition and topography where the dumpsite is situated play important roles in the diversity and abundance of flora and fauna species that inhabit the polluted environment.

The proportion of soil mixture has also been linked to leachate seepage and is directly proportional to the carbon uptake, tolerance and diversity of species in polluted soils (Obasi *et al.*, 2015, Onwe *et al.*, 2019). Ecological interactions between plants and soil are established during the bioaccumulation process.

Carbon uptake is one of the metabolic processes in plants during which carbon dioxide is converted into metabolically active organic carbon.

During photosynthesis, carbon utilises ATP and NADPH to assimilate carbon dioxide to form carbohydrates translocated and stored in different plant

parts. The TSC and SCO₂E evaluation at active dump station A suggests that the Solanaceae species best sequestered carbon with reference to studies on the assessment of the phytoremediation potential of *Solanum melongena* L. (Solanaceae) (Singh *et al.*, 2017). This work affirmed that species in the Solanaceae family possess high metal accumulation capacity and are heavy metal tolerant. The accumulation potential is associated with an increase in biomass and carbon uptake (Singh *et al.*, 2017).

Species in the Solanaceae family employ rhizo-filtration strategies in the removal and storage of organic carbon in contaminated soils. In this study, the invasive *Physalis angulata* sequestered the most carbon at station A (Waterworks).

Therefore, it can be recommended as a potential phytoremediator in destroyed ecosystems. Species in the Aizoaceae family sequestered the most carbon at station B (KpiriKpiri); the phytoremediation potential of Aizoaceae species, especially *Mesembryanthemum crystallinum* L., were reported by Sliwa-Cebula *et al.* (2022).

Species in the Aizoaceae family are known to grow in toxic ecosystems and thrive in poorly enriched substrates, which allows the interaction with rhizosphere bacteria. Potentially toxic elements, such as Na and Zn, are translocated from roots to shoots, suggesting their ability to initiate phytoextraction mechanisms.

This report agrees with the results of this study, confirming that species in the Aizoaceae (*Trianthema portulacastrum* L) are potential biotic pollutant remediators in soils, even though they were not

encountered at the other active dump station (A). In dormant or abandoned dump station C (Newlayout), the soils were composed mainly of 65.8% sand, 15.77% silt and 18.38% clay, according to a report by Obasi *et al.* (2015). The high proportion of sand in the soil is notably the reason for major leachate infiltration observable within the site.

The soil hydraulic conductivity was estimated to be about 125.3 cm/h. Abiotic factors, such as the soil composition, leachate seepage and age of dumpsite, play vital roles in the species abundance and diversity encountered at the abandoned dumpsites (stations C and D). Plant species encountered at the dormant site account for over 50% of the abundance and composition of all evaluated locations. The dry biomass weight, TSC and SCO₂E determined at the inactive dumps confirmed that the graminoids stored the most carbon.

Species in the Poaceae have continuously been used for restoration of degraded soils and waste lands. *Eleusine indica*, for instance, stood out as the most important grass species in this study. This grass species has a high tolerance to low rainfall or no rainfall and sprouts even after environmental stress events, such as flooding, fire and drought (Yang *et al.*, 2019).

The singular dominance of this grass species at station C (abandoned dumpsite) may be associated with the form of pollen dispersal and its capacity to break dormancy (Pandey *et al.*, 2024). He *et al.* (2017) also confirmed that species in the Poaceae and Cyperaceae families can be used for the restoration of degraded lands.

The success of the grass and sedge species as first colonisers and initiators of primary succession in degraded soils has been attributed to carbon dioxide sequestration and their ability to bioaccumulate or degrade toxic elements activated during interactions with microbes in the soil, as reported by Burpujari (2008).

Nitrogen-fixing legumes accounted for the highest biomass and total organic carbon sink estimated at station E (Presco).

The successful species dominance in the Fabaceae family is linked to the presence of an inter-rooting system, which improves and promotes the quantity and quality of carbon sequestration in soil aggregates.

These rooting mechanisms promote nitrogen production and are associated with an increase in organic carbon sequestration in the soil under high nitrogen conditions.

The nitrogen conditions are estimated to contribute to a 33% reduction in carbon dioxide outflow during photosynthesis (Wafaa *et al.*, 2024).

A recent study on plant–soil interactions reported that species in the Fabaceae family in association with nitrogen-fixing bacteria in the soil form a host relationship that can increase plant stress resistance, soil nutrient availability, toxic molecule degradation and phytohormone production (Alsafran *et al.*, 2022).

The species carbon uptake mechanism evaluated in this study revealed that the species sequestering the most carbon inhabited active dump stations; however, the results from the

ANOVA for TSC and SCO₂E revealed significant differences at a 95% confidence interval only at the abandoned dumpsites.

This indicates that the species at the abandoned dumpsites are excellent carbon sequesters and thus should be considered for phytoremediation in disturbed or destroyed habitats.

The abundance, tolerance and carbon uptake of plants inhabiting open dumpsites and the possible association of pollutant-tolerant species that perform phytoremediation have been addressed in this study.

These results have led to ongoing investigations on contamination levels and the type of phytoremediation strategies employed by encountered plant species at all investigated study sites.

CONCLUSIONS

In this study, the methods employed in the measurement of diversity and biomass aided in the identification of species tolerant to potentially toxic pollutants in open waste disposal stations. Carbon sequestration estimation is a useful method employed in the restoration of degraded soils and in the improvement of agricultural productivity, as shown by the ANOVA of TSC and SCO₂E in this research.

In both the active and dormant dumpsites investigated, only the dormant or abandoned dump stations showed a significant difference ($p < 0.05$). At stations C and D, alpha values (p) were less than 0.001.

This showed that the carbon storage results obtained in this research were useful and that the propagation of plant species found at the abandoned dumpsites

could serve as an economic and ecologically friendly method of recovering waste soils and destroyed habitats.

This investigation provides baseline data for waste management agencies and environmental stakeholders to draw informed conclusions concerning biodiversity and conservative measures in disturbed ecosystems, especially the recovery of abandoned waste disposal sites.

The inventories in this study notably contain invasive and economic species found around waste disposal sites and provide relevant information on the ecology of the dump ecosystems studied.

Further research on the impact of potentially toxic pollutants on the genetic makeup of plants inhabiting disposal sites is recommended.

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REFERENCES

- Abenu, A.; Elejuku, A.A.; Onuzulike, C.O.; Bartholomew, J.L. Recovery and Recycling of Municipal Solid Waste in Kaduna Metropolis: Realities and Challenges. *Journal of Science and Sustainable Development* **2021**, *8*, 45-54. <https://dx.doi.org/10.4314/jssd.v8i1.4>

- Andersen, M.E.** Estimating Plant Densities Using Transects. In *Tested studies for laboratory teaching*. Proceedings of the 14th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 1993, 14, 51-56.
- Alsafran, M.; Usman, K.; Ahmed, B.; Rizwan, M.; Saleem, M.H.; Al Jabri, H.** Understanding the Phytoremediation Mechanisms of Potentially Toxic Elements: A Proteomic Overview of Recent Advances. *Frontiers in Plant Science* **2022**, 13, 881-242. <https://doi.org/10.3389/fpls.2022.881242>
- Burpujari, D.** Studies on the Occurrence and Distribution of Some Tolerant Plant Species in Different Spoil Dumps of Tikak Opencast Mine. *The Ecoscan* **2008**, 2 (2), 255-260.
- Collins, H.; Wizar, I.; Ibeaja, A.C.** Utilizing Biogas Technology as Alternative Energy Source in Nigerian Urban and Peri-Urban Centers. *World Journal of Innovative Research* **2019**, 7 (2), 71-80.
- Eneji, I.S.; Obinna, O.; Azua, E.T.** Sequestration and Carbon Storage Potential of Tropical Forest Reserves and Tree Species Located Within Benue State of Nigeria. *Journal of Geoscience and Environment Protection* **2014**, 2, 157-166. <http://dx.doi.org/10.4236/gep.2014.22022>
- Hachiya, T.; Sugiura, D.; Kojima, M.; Sato, S.; Yanagisawa, S.; Sakakibara, H.; Terashima, I.; Noguchi, K.** High CO₂ Triggers Preferential Root Growth of *Arabidopsis thaliana* via Two Distinct Systems Under Low pH and Low N Stresses. *Plant and Cell Physiology* **2014**, 55, 269-280. <https://doi.org/10.1093/pcp/pcu001>
- He, C.; Zheng, X.; Yan, X.; Zheng, J.; Wang, M.; Tan, X.; Qiao, L.; Chen, S.; Yang, Z.; Mai, B.** Organic contaminants and heavy metals in indoor dust from e-waste recycling, rural, and urban areas in South China: Spatial characteristics and implications for human exposure. *Ecotoxicology and Environmental Safety* **2017**, 140, 109-115. <https://doi.org/10.1016/j.ecoenv.2017.02.041>
- Hutchinson, J.; Dalziel, J.M.; Keay, R.W.J.; Hepper, N.** *Flora of West Tropical Africa*, Second edition. The White Friars Press Ltd, London, U.K. 1959, Vol. 1 and 2.
- Ikpe, A.E.; Etim, P.J.; Akani-Ubiam, E.N.** Assessment of the Waste Management System and Its Implications. 2020, pp 23-34.
- Margalef, R.** Temporary Succession and Spatial Heterogeneity in Phytoplankton. In *Perspectives in Marine Biology*, Buzzati-Traverso, A., Ed.; University of California Press, Berkeley, U.S.A., 1958, pp 323-347.
- Michael, T.; Dananjali, G.; Naoki, H.; Anke, M.; Saman, S.** Effects of Elevated Carbon Dioxide on Photosynthesis and Carbon Partitioning: A Perspective on Root Sugar Sensing and Hormonal Crosstalk. *Frontiers in Physiology* **2017**, 8. <https://doi.org/10.3389/fphys.2017.00578>
- Nagendran, R.; Selvam, A.; Joseph, K.; Chiemchaisri, C.** Phytoremediation and Rehabilitation of Municipal Solid Waste Landfills and Dumpsites: A Brief Review. *Waste Management* **2006**, 26, 1357-1369. <https://doi.org/10.1016/j.wasman.2006.05.003>
- Nodza, G.I.; Anthony, R.U.; Onuminya, T.O.; Ogundipe, O.T.** Floristic Studies on Herbaceous and Grass Species Growing in the University of Lagos, Nigeria. *Tanzania Journal of Science* **2021**, 47 (1), 80-90.
- Nwagwu, N.G.; Alwadood, J.A.; Iheanacho, N.M.; Ezurike, C.V.; Kopteer, E.P.; et al.** Spatial Analysis

- of Solid Waste Collection Sites in Abakaliki Metropolis. *World Journal of Advanced Research and Reviews* **2024**, 21 (1), 2382-2387.
- Obasi, A.I.; Ekpe, I.I.; Igwe, E.O.; Nnachi, E.E.** The Physical Properties of Soils Within Major Dumpsites in Abakaliki Urban, Southern Nigeria, and Their Implications for Groundwater Contamination. *International Journal of Agriculture and Forestry* **2015**, 5 (1), 17-22.
<http://dx.doi.org/10.5923/j.ijaf.20150501.03>
- Onwe, M.R.; Nwankwor, G.I.; Ahiarakwem, C.A.; Abraham, E.M.; Emberga, T.T.** Assessment of geospatial capability index for siting waste dump/landfill to control groundwater geopollution using geographic information system (GIS) approach: case study of Abakaliki area and environs, Southeastern Nigeria. *Applied Water Science* **2019**, 10:12 (2020), 11-19.
<https://doi.org/10.1007/s13201-019-1087-5>
- Okunlola, A.; Ibiro, A.; Sanusi, O.; Akinbola, T.** Net Carbon Sequestration and Emission Potential on Lawns in Federal University of Technology, Akure (FUTA), Ondo State, Nigeria. *International Journal of Research in Agriculture and Forestry* **2019**, 6 (3), 1-6.
- Ousmane, L.M.; Salamatou, A.I.; Iro, D.G.; Pierre, O.** Species Diversity and Distribution of Ruderal Flora on Landfills in Maradi City, Niger. *International Journal of Environment Agriculture and Biotechnology* **2017**, 2 (2), 715-722.
<http://dx.doi.org/10.22161/ijeab/2.2.20>
- Pandey, S.; Jha, A.K.; Singh, T.N.** A Sustainable Approach for Stabilization of Coal Mine Overburden Waste: A Critical Appraisal. *Indian Geotechnical Journal* **2024**, 1-19.
<http://dx.doi.org/10.1007/s40098-024-00987-6>
- Pielou, E.C.** The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* **1966**, 13, 131-144.
[https://doi.org/10.1016/0022-5193\(66\)90013-0](https://doi.org/10.1016/0022-5193(66)90013-0)
- Savaci, G.; Oksuz, C.** Investigation of heavy metal concentrations in soil caused by wild storage dumpsite in Kastamonu city. *Turkish Journal of Forest Science* **2020**, 4 (1), 26-39.
<https://doi.org/10.32328/turkjforsci.703836>
- Sharma, J.K.; Kumar, N.; Singh, N.P.; Santal, A.R.** Phytoremediation Technologies and Their Mechanism for Removal of Heavy Metals from Contaminated Soil: An Approach for a Sustainable Environment. *Frontiers in Plant Science* **2023**, 14.
<https://doi.org/10.3389/fpls.2023.1076876>
- Shannon, C.E.; Weiner, W.** *The Mathematical Theory of Communication*. The University of Illinois Press, Urbana, U.S.A., 1949, 177 pp.
- Schlesinger, W.H.; Amundson, R.** Managing Soil Carbon Sequestration: Let's Get Realistic. *Wiley Global Change Biology* **2018**, 25 (2), 386-389.
<https://doi.org/10.1111/gcb.14478>
- Schlesinger, W.H.; Lichter, J.** Limited Carbon Storage in Soil and Litter of Experimental Forest Plots Under Increased Atmospheric CO₂. *Nature* **2001**, 411 (6836), 466-469.
<https://doi.org/10.1038/35078060>
- Sehrish, M.; Muhammed, S.; Muhammed, R.T.; Adnan, S.; Muhammed, S.N.; Muhammed, H.T.B.; Muhammed, S.H.; Saleha, S.; Muhammed, T.A.; Muhammed, H.; Muhammed, A.S.** Interaction between bacterial endophytes and host plants. *Frontiers in Plant Science* **2022**, 10, 92-105.

- <https://doi.org/10.3389/fpls.2022.1092105>
- Singh, J.S.; Naik, R.; Bahuguna, A.; Kumar, A.; Sharma, N.** Habitat Quality Characterization and Management of Asan Wetland Biodiversity. *International Journal of Ecology and Environmental Sciences* **2024**, *50* (4).
<https://doi.org/10.55863/ijees.2024.0098>
- Singh, S.; Fulzele, D.P.** Phytoextraction of arsenic using a weed plant *Calotropis procera* from contaminated water and soil: growth and biochemical response. *International Journal of Phytoremediation* **2021**, *23* (12).
<https://doi.org/10.1080/15226514.2021.1895717>
- Singh, H.; Malik, S.A.; Anukrati.; Souza, R.D.; Chaturvedi, P.** Assessment of Phytoremediation Potential of *Solanum melongena* L. *International Journal of Environmental Science Development & Monitoring* **2017**, *8* (1), 17-37.
<https://dx.doi.org/10.37622/IJESDM/8.1.2017.17-37>
- Singh, J.S.; Lauenroth, W.K.; Steinhorst, R.K.** Review and Assessment of Various Techniques for Estimating Net Aerial Primary Production in Grasslands from Harvest Data Author(s) Terms and Conditions. *The Botanical Review* **1975**, *41*, 181-23226.
<http://dx.doi.org/10.1007/BF02860829>
- Simpson, E.H.** Measurement of Diversity. *Nature* **1949**, *163*, 163-688.
<https://doi.org/10.1038/163688a0>
- Sliwa-Cebula, M.; Koniarz, T.; Szara-Bak, M.; Baran, A.; Miszalski, A.; Kaszycki, P.** Phytoremediation of Metal-Contaminated Bottom Sediments by the Common Ice Plant (*Mesembryanthemum crystallinum* L.) in Poland. *Journal of Soils and Sediments* **2023**, *23*.
<https://doi.org/10.1007/s11368-022-03401-x>
- Sliwa-Cebula, M.; Kaszycki, P.; Kaczmarczyk, A.; Nose, M.; Lis-Kryzyscin, A.; Miszalski, Z.** The Common Ice Plant (*Mesembryanthemum crystallinum* L.)-Phytoremediation Potential for Cadmium and Chromate-Contaminated Soils. *Plants* **2020**, *9* (9).
<https://doi.org/10.3390/plants9091230>
- Thompson, D.; Bush, E.; Kirk-Ballard, H.** Lead Phytoremediation in Contaminated Landscape Plants. *Journal of Geoscience and Environment Protection* **2021**, *9* (5), 152-164.
<https://doi.org/10.4236/gep.2021.95011>
- Gilbert, T.; Kapi, D.; Toua, V.** Diversity and Local Transformation of Indigenous Edible Fruits in Sahelian Domain of Cameroun. *Journal of Animal and Plant Sciences* **2017**, *26* (2), 5289-5300.
- Wafaa, S.A.; Luma, A.S.; Dunya, A.** Employing Phytoremediation Methods to Extract Heavy Metals From Polluted Soils. *Ecological Engineering and Environmental Technology* **2024**, *25* (6), 352-361.
<https://doi.org/10.12912/27197050/187775>
- Yang, Y.; Tilman, D.; Furey, G.; Lehman, C.** Soil carbon sequestration accelerated by restoration of grassland biodiversity. *Nature Communications* **2019**, *10*, 71.
<https://doi.org/10.1038/s41467-019-08636-w>
- Yakubu, J.A.** The Waste Management System in Low Income Areas of Jos, Nigeria: The Challenges and Waste Reduction Opportunities. PhD Thesis, University of Brighton, October 2017.
- Yan, A.; Wang, Y.; Tan, S.N.; Mohammed, L.M.Y.; Subhadip, G.; Chen, Z.** Phytoremediation: A Promising Approach for Revegetation of Heavy Metal-Polluted Land. *Frontiers in Plant Science* **2020**, *11*.

<https://doi.org/10.3389/fpls.2020.00359>
Yin, F.; Li, J.; Wang, Y.; Yang, Z.
Biodegradable Chelating Agents for
Enhancing Phytoremediation:
Mechanisms, Market Feasibility, and

Future Studies. *Ecotoxicology and
Environmental Safety* **2024**, 272.
<https://doi.org/10.1016/j.ecoenv.2024.116113>

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