



Floral Distribution of a Sub-Bituminous Coal Dumpsite in Enugu, Nigeria

Imade Y. Nsa^{1*}, Oyetola O. Oyebanji², Eric E. Igbini³ and Ayodeji A. Odunsi¹

¹ Department of Microbiology, Faculty of Science, University of Lagos, Lagos, Nigeria, ² Department of Botany, Faculty of Science, University of Lagos, Lagos, Nigeria, ³ Assured Turnkey Solutions, Johannesburg, South Africa

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*Correspondence:

Imade Y. Nsa
insa@unilag.edu.ng

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The remnant floral diversity of a naturally reclaimed area proximal to an abandoned mine was assessed. The coal mine site, the Incident zone (IZ) and an unsullied site, the Control zone (CZ), were sampled. Using a 5 m² quadrat, the floristic composition was determined by the occurrence, distribution analysis, and species diversity indices. The study revealed a degraded vegetation type and recorded a total of 60 species, 53 genera and 27 families. Both the IZ and CZ shared 26.67% species similarity, while 36.67% are were unique to each zone. Five species were dominant (*Ageratum conyzoides*, *Panicum maximum*, *Calopogonium mucunoides*, *Chromolaena odorata*). While the dominant genera vary between IZ (*Borreria*, *Dioscorea*, *Ipomoea*, and *Phyllanthus*) and CZ (*Desmodium*, *Euphorbia*, and *Ipomoea*), Asteraceae and Poaceae were the dominant families in both zones. Forbs were the most dominant life forms in both zones; *Cyclosorus* sp. and *Adiantum* sp. were only found on the IZ, whereas, *Kyllinga erecta* and *Mariscus alternifolius* were exclusive to the CZ. Our results reflect that species composition and vegetation paradigm in the study area could be influenced by coal mining, farming, infrastructural installations and climate. Hence, we suggest future studies to investigate how the species adapt to the environment. Although most of the species encountered belonged to lower-risk conservation, the conservation of the species to this area is imperative.

Keywords: sub-bituminous coal, flora, diversity index, conservation status, incident zone, control zone

INTRODUCTION

Coal is a significant source of energy globally (National Research Council [NRC], 1995; Zou et al., 2016; International Energy Agency [IEA], 2018; Ritchie and Roser, 2019). It is one of the most abundant fossil fuel resources present in Nigeria (Ezekwe and Odukwe, 1980; Ogunsola, 1991), comprising bituminous, sub-bituminous, and lignite belts (Behre, 2006). Its most dominant form in Nigeria, sub-bituminous coal (Chukwu et al., 2016), is characterized by a high calorific value of (5,000–6,000 cal/g or 5,500–6,500 cal/g air-dried), low ash and low sulfur content (Afonja, 1979).

Coal mining, its related activities, including total clearance of vegetation and the indiscriminate disposal of waste coal material such as coal spoils and discards, which are usually stockpiled in the form of dumps, cause land degradation (Singh et al., 2002; Ghose, 2004; Ekka and Behera, 2011), thus, inducing changes in soil structure, typically the physical, chemical and microbiological properties of soil, as well as the destruction of vegetation which ultimately disrupt the functioning of ecosystems (Kundu and Ghose, 1997; Sheoran et al., 2010).

Due to plants' inability to move, they have to deal with changes in their environment (Sanchita, 2018). Environmental changes due to mine waste cause loss of biodiversity (Sheoran et al., 2010). Under a narrow range of conditions in the environment, plant community structure depends on plants' capabilities to develop certain adaptive morphological and physiological features (Dazy et al., 2009).

The loss of vegetation due to coal mining activities has become topical (Sarma, 2005; Huang et al., 2014). Perhaps, these activities may have influenced the concurrent colonization of the coal dumpsites by different invasive plant species, which resulted in the continuous disruption of vegetation. Previous studies have recorded several invasive plant species present in the coal mine dumpsites undergoing rehabilitation in different parts of the world, e.g., Columbia, India, and Indonesia (Sarma, 2005; Hazarika et al., 2006; Sánchez-Pinzón et al., 2010; Ekka and Behera, 2011; Singh, 2011; Komara et al., 2016; Novianti et al., 2017; Yusuf and Arisoelaningsih, 2017; Hapsari et al., 2020). Together, those studies identified associated plant species such as *Adiantum* sp., *Ageratum conyzoides* (Mill.) M. Sharma, *Alternanthera sessilis* L., *Chromolaena odorata* (L.) R. M. King and H. Rob., *Ipomoea cairica* (L.) Sweet, *Oldenlandia corymbosa* L., *Panicum maximum* Jacq., *Pennisetum purpureum* Schumach., *Tridax procumbens* L., and *Urena lobata* L. to coal mine dumpsites. To our knowledge, there are no detailed studies documenting the plant species inventories of coal mining sites in Nigeria, especially Enugu (the Nigerian Coal City that used to be home to Iva Valley, Ogbete, Onyeama, and Okpara mines (Sikakwe et al., 2015; Agbalagba and Uzo, 2018). Nonetheless, there is an environmental impact assessment (EIA) report which highlighted the effects of coal mining activities on biodiversity, especially on economic tree species (e.g., *Khaya ivorensis* and *Milicia excelsa*) in Akwueke and Iva Valley communities within the Enugu Coal City (Ogbonna et al., 2015). Other previous studies focused instead of floral composition on the geo-environmental characteristics of the Okpara, Onyeama, and Ribadu coal mine sites (Sikakwe et al., 2015; Sikakwe, 2017).

Drawing from the lessons of the occurrence of the devastation by coal mining on the ecosystem (in abandoned mined lands) and its subsequent revegetation from different regions of the world (Baig, 1992; Skousen et al., 1994; Sheoran et al., 2010; Yang et al., 2015; Pauletto et al., 2016; Buta et al., 2019), it was essential to examine how coal mining and its concomitant wastes have impacted the floral distribution in the Coal Camp/Ogbete area. We evaluated the plant diversity by (1) comparing the remnant species in the polluted coal site (IZ) and an undisturbed site (CZ) and by the assessment of the conservation status of the species within the study area.

MATERIALS AND METHODS

Study Area

The study was carried out around the defunct coal mines in the Coal Camp located at Udi (6° 25' N, 7° 28' E), Enugu State (Figure 1 and Table 1) between 2014 and 2016 (Nsa et al., 2017). The map for the study site was generated with the ArcGIS software (Environmental Systems Research Institute [ESRI], 2014). Enugu has different vegetation types ranging from the tropical rainforest in the south (where Udi is) to open grassland and savannah in the north (Obi, 2009). The site is surrounded by hills and disturbed secondary regrowth forest vegetation comprising trees, shrubs, and herbs. Although the decline in mining began over 40 years ago, the operations were stalled entirely around 2005. The project area has experienced infrastructural development, urbanization, and farming activities over this period. The occupants of the study area were farmers, former workers of the defunct mine, and traders. For this study, the area near the coal mine, visibly contaminated with coal wastes, was referred to as the Incident zone (IZ), and an uncontaminated area referred to as the Control Zone (CZ). The three criteria considered prior to site selection were: (i) sampling points cover and spread, (ii) species heterogeneity, and (iii) coal mining sites.

Climatic Data

The climatic data for the site covering the period from January 1, 2014, through December 31, 2016, were obtained from two sources; Power SRB, NASA (<https://power.larc.nasa.gov/>; last accessed 2020/10/10; Briggs et al., 2003) and Nigerian Meteorological Agency (NIMET). The Global Positioning System (GPS; Garmin MAP 64S) coordinates of the plot in the Coal Camp were used to retrieve the precipitation data from NASA, whereas NIMET rainfall data covered the entire Enugu region (Chukwuike, 2018).

Sampling

Nine geo-referenced sampling points (IZ = 7 and CZ = 2) were systematically established for biodiversity assessment (Figure 1). The limited sampling points were attributable to acute environmental degradation and habitat fragmentation due to patchiness within the IZ. Two points (about 5 km away) free of mining activities outside the IZ were assessed to compare species presence and absence. Biodiversity assessment was conducted using a 5 m² quadrat sampling method (Barker, 2001; Unanaonwi and Amonum, 2017). The choice of the quadrat size was determined with consideration of the landscape of the study site. The points with heterogenous populations were selected for adequate representation of the different species. The coverage, abundance, frequencies of the species and life-form classes within the sampling areas were recorded.

Species Identification

Taxa identification and classification were made onsite, while representatives from indeterminate species were collected and preserved as described by Radford et al. (1974). The two

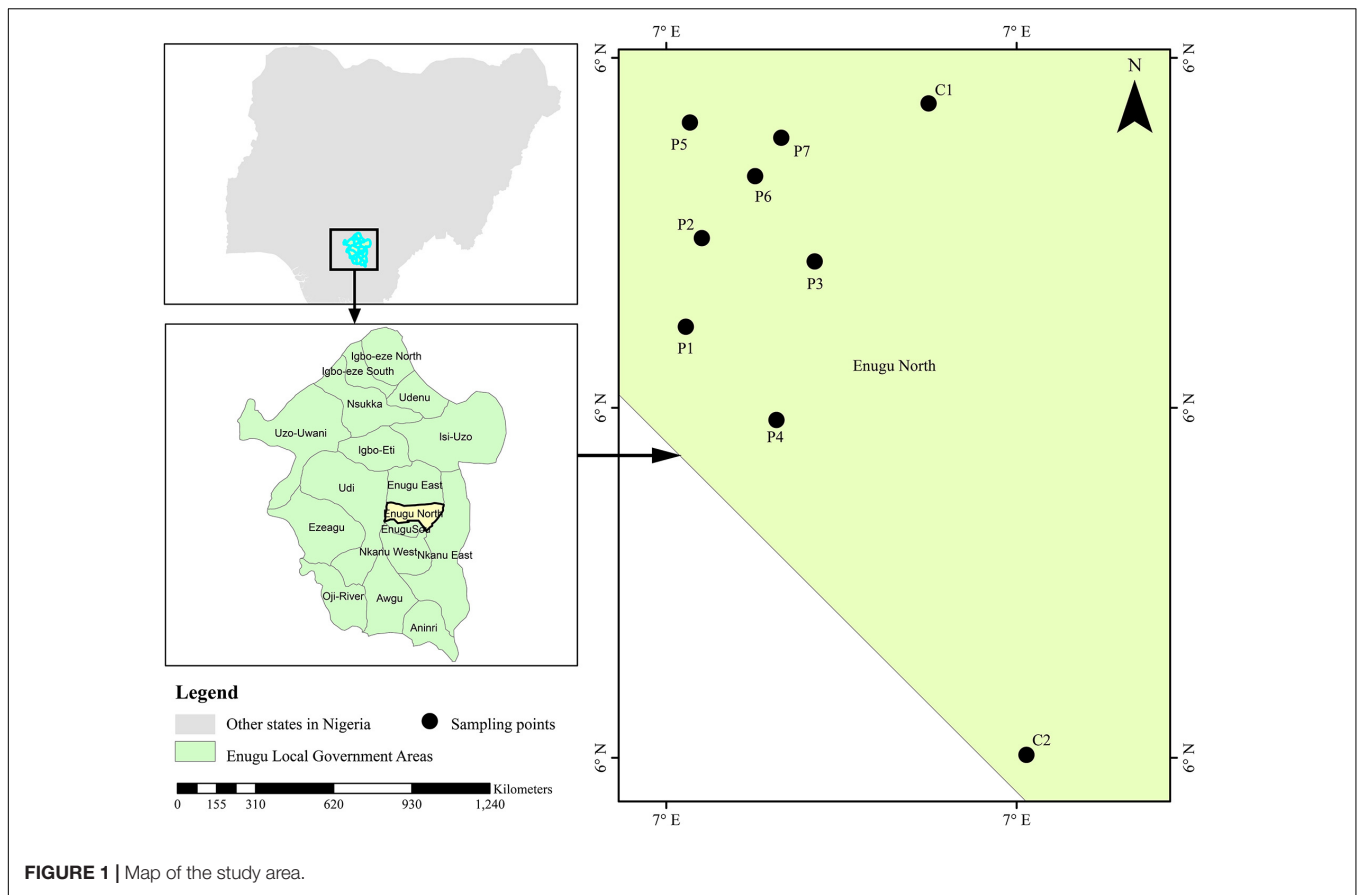


TABLE 1 | Climate data (NASA and NIMET) and onsite temperature.

Months	Climate NASA (SRB)									Climate (NIMET, 2017)		
	2014			2015			2016			Year	Rainfall (mm)	Temp. (°C)
	Precipitation (mm)	Temp. (°C)	Relative humidity	Precipitation (mm)	Temp. (°C)	Relative humidity	Precipitation (mm)	Temp. (°C)	Relative humidity			
January	14.19	25.4	73.76	0.98	23.55	64.49	4.12	24.7	55.82	2014	1875.3	28
February	24.47	26.31	79.55	18.24	26.71	81.85	3.66	27.2	64.29	2015	1862.3	27.4
March	39.03	26.52	84.82	92.92	26.71	82.02	109.54	27.74	81.99	2016	1823.4	29.1
April	107.36	26.48	85.41	46.42	26.87	82.6	70.76	27.51	83.76			
May	120.3	26.35	88.16	98.61	26.41	86.6	152.77	26.62	86.4			
June	104.38	25.85	88.87	165.3	25.57	88.4	159.97	25.6	87.46			
July	128.6	25.26	88.99	172.7	25.42	87.85	220.36	25.01	88.64			
August*	185.84	24.8	87.97	106.02	25.29	87.82	310.15	24.86	89.39			
September	175.85	24.94	89.83	226.64	25.3	89.05	294.03	25.03	89.65			
October	132.26	25.45	88.33	157.9	25.48	88.89	229.41	25.7	88.14			
November	43.74	25.93	86.89	81.14	26.01	80.6	44.18	26.49	82.14			
December	0.3	25.43	79.41	0.2	22.96	58.43	8.85	25.22	72.71			
Total	1727.24			1076.32			1607.82					
Average (°C)		25.72	85.18		25.51	81.51		25.96	80.9			

*Month of sample collection August.

approaches used for the species identification were based on: (1) the morphological description in Flora, manuals and monographs (Hutchinson and Dalziel, 1954, 1958, 1963, 1968; Alston, 1959; Keay et al., 1964; Hutchinson et al., 1972;

Lowe and Stanfield, 1974; Akobundu and Agyakwa, 1998) and (2) the comparison of the plant specimen samples with the preserved dried samples at the University of Lagos Herbarium (Department of Botany), Nigeria. These identification methods

have been used in previous studies (Adeniyi et al., 2016; Adeonipekun et al., 2018). Identification of species was delimited to the genus level for species that had incomplete morphological features. The plant families followed the Angiosperm Phylogeny Group (The Angiosperm Phylogeny Group [APG], 2016), while the species nomenclature and authorities were validated by the International Plant Name Index database (International Plant Names Index [IPNI], 2020). All plant samples collected were used solely for identification purposes.

Data Analysis

Species presence and absence were recorded for each sampled plot, followed by the comparative floristic analyses of the two zones (IZ and CZ) using four descriptive statistics and diversity indices (Patel et al., 2012, Patel et al., 2020; Oyebanji et al., 2020). The descriptive statistics include frequency (%), relative frequency (%), density (plant/m²), and relative density (%) while the diversity indices were performed using Dominance, Evenness, Shannon—Wiener, and Simpson's indices (Simpson, 1949; Shannon and Weaver, 1963; Magurran, 1988) incorporated in Paleontological Statistical software (PAST v 2.17c, Hammer et al., 2001). The five-category life forms (climber, forb, grass, shrub, and tree) typical of the tropics were adopted to describe the forest morphology of the study area based on the classification scheme of Mueller-Dombois (1972).

Conservation Status Assessment

The conservation status of the species was classified as Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in The Wild (EW), and Extinct (EX) based on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2021). The species without complete taxonomic identification could not be assessed and were designated as Not Determined (ND).

RESULTS

Ecosystem and Habitat Characteristics

In the 3 years reported, the average precipitation rate was highest in 2016 (Table 1). The habitat ranged from degraded secondary forests to patches of flood plains. Some species are known to occupy flooded areas. Based on the IUCN's Habitat and Ecology ranking, 10 wetland (inland) species were present (*Alternanthera sessilis* L., *Ageratum conyzoides* (Mill.) M. Sharma, *Colocasia esculenta* (L.) Schott., *Commelina diffusa* Burm. F., *Eleusine indica* (L.) Gaertn., *Kyllinga erecta* Schumach., *Ipomoea cairica* (L.) Sweet, *Imperata cylindrica* (L.) Raeusch., *Pennisetum pupureum* Schumach., *Urena lobata* L.) and *Oldenlandia corymbosa* associated with the Artificial/Aquatic and Marine habitat. Other wetland species encountered without an IUCN status include *Sida acuta* Burm. fil., *Desmodium triflorum* (L.) DC., *Centrosema pubescens* Benth., *Calopogonium mucunoides* Desv., *Peltophorum pterocarpum* (DC.) K. Heyne, *Euphorbia heterophylla* L., *Borreria ocymoides* (Burm. F.) DC. *Panicum maximum* Jacq., and *Axonopus compressus* (Sw.) P. Beauv.

Overall Species Distribution

The study revealed a total of 60 species belonging to 53 genera and 27 families in the sampled area (Figures 2, 3A,B and Table 2). The environment was dominated by two angiosperm families, Asteraceae and Poaceae, each represented by seven species. The genus *Ipomoea* L. ($n = 3$ species) and five other genera [*Borreria* G. Mey, *Desmodium* Desv., *Dioscorea* Plum. Ex L., *Euphorbia* L., and *Phyllanthus* L. ($n = 2$ species each)] were dominant. The distribution of the 60 species into the life-form categories was as follows: forb (27 species), climber (12 species), grass (9 species), shrub (7 species), and tree (5 species) (Figure 3C).

Species Diversity Comparison Between IZ and CZ

Comparatively, each zone had 38 species spread across genera (IZ = 34 and CZ = 35) and families (IZ = 18 and CZ = 19) (Figure 3A and Table 2). The dominant species within the IZ were *Ageratum conyzoides* (Mill.) M. Sharma (frequency = 77.78%, $R.F = 10.14\%$, density = 0.28 m², and $R.D = 10.29\%$), *Panicum maximum* Jacq. (frequency = 66.67%, $R.F = 8.70\%$, density = 0.24 m², and $R.D = 8.82\%$), *Calopogonium mucunoides* Desv. (frequency = 55.56%, $R.F = 7.25\%$, density = 0.2 m², and $R.D = 7.35\%$), and *Chromolaena odorata* (L.) R. M. King and H. Rob (frequency = 55.56%, $R.F = 7.25\%$, density = 0.2 m² and $R.D = 7.35\%$).

In both IZ and CZ, *Ipomoea* ($n = 2$ species each) was the dominant genus. Three genera (*Borreria*, *Dioscorea*, and *Phyllanthus*) and two genera (*Desmodium* and *Euphorbia*) each represented with two species were dominant in both zones.

Twenty-two species were exclusive to each zone, while 16 species were common to both zones; *A. conyzoides*, *Asystasia gangetica* (L.) T. Anderson, *Axonopus compressus* (Sw.) P. Beauv. *Brachiaria deflexa* (Schumach) C.E. Hubb. ex Robyns, *C. mucunoides*, *C. odorata*, *C. esculenta*, *Desmodium triflorum* (L.) DC., *Emilia coccinea* (Sims) G. Don, *Ipomoea cairica* (L.) Sweet, *Manihot esculenta* Crantz, *O. corymbosa*, *P. maximum*, *Setaria barbata* (Lam.) Kunth, and *Synedrella nodiflora* (L.) Gaertn., and *Urena lobata* L. (Table 2 and Figure 3D).

The floristic inventory revealed that there were eight families (Commelinaceae, Costaceae, Dioscoreaceae, Loganiaceae, Melastomaceae, Passifloraceae, Pteridaceae, and Thelypteridaceae) and nine families (Anacardiaceae, Cucurbitaceae, Cyperaceae, Lamiaceae, Onagraceae, Piperaceae, Portulacaceae, Ulmaceae, and Urticaceae) unique to the IZ and CZ, respectively; the zones had ten families in common. The shared families were Acanthaceae, Amaranthaceae, Araceae, Asteraceae, Convolvulaceae, Euphorbiaceae, Fabaceae, Malvaceae, Rubiaceae, and Poaceae (Figure 3B). Among these, Asteraceae and Poaceae were dominant in the IZ and CZ, represented with six and five species, respectively (Table 2). All the life-form categories were found in the IZ and CZ (Figure 3B).

The diversity indices revealed that Plot 2 had the highest diversity, as confirmed by Simpson, Shannon and Margalef values of 0.09, 2.66, and 4.35, respectively. In contrast, Plot 4 had the highest Dominance (0.50), Evenness (~1.00), and equitability values of (~1.00). The diversity indices for the pooled

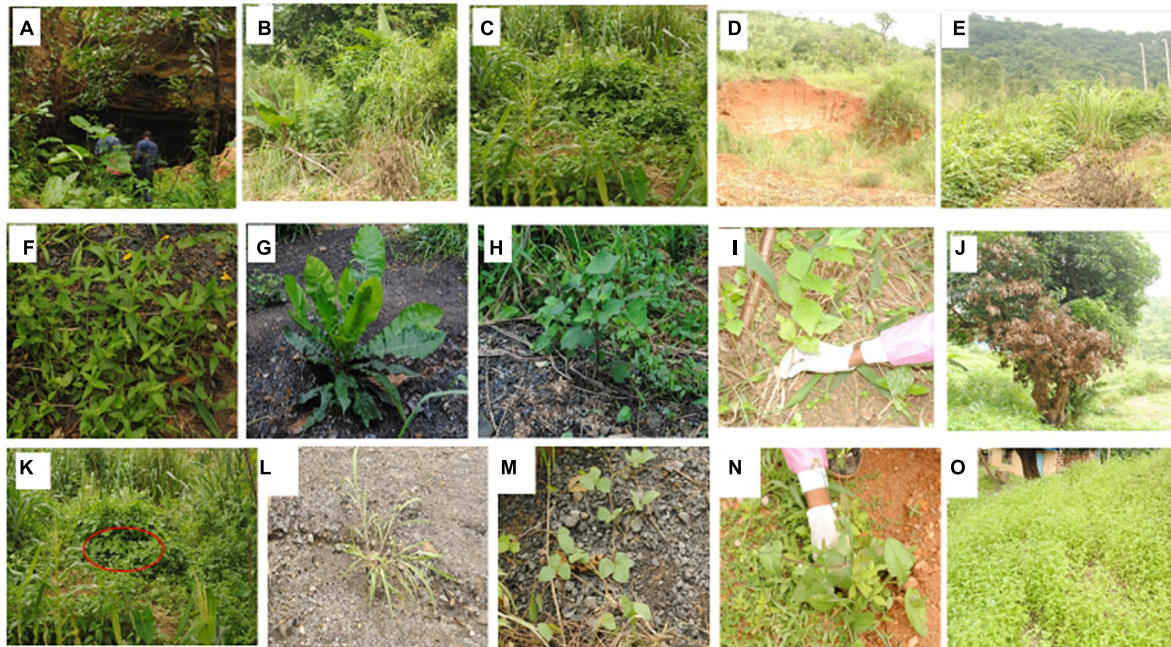


FIGURE 2 | Vegetation view and representative species of the IZ and CZ. **(A)** Coal cave. **(B,C)** Disturbed herbaceous vegetation on the coal dumpsite, **(D)** Hill surrounding area. **(E)** Physiognomy of the control zone vegetation. **(F)** *Aspilia africana* [IZ]. **(G)** Juvenile *Anthocleista vogelii*. **(H)** *Urena lobate*. **(I)** *Sida acuta*. **(J)** *Mangifera indica*. **(K)** Twinning *Luffa cylindrica* (red circle) around other species. **(L)** Juvenile *Panicum maximum*. **(M)** *Calopogonium mucunoides*. **(N)** *Emilia coccinea* and **(O)** Lush of *Ageratum conyzoides*. Photo credits: by I. Y. Nsa, O. O. Oyebanji, G. U. Anorue, and A. A. Odunsi.

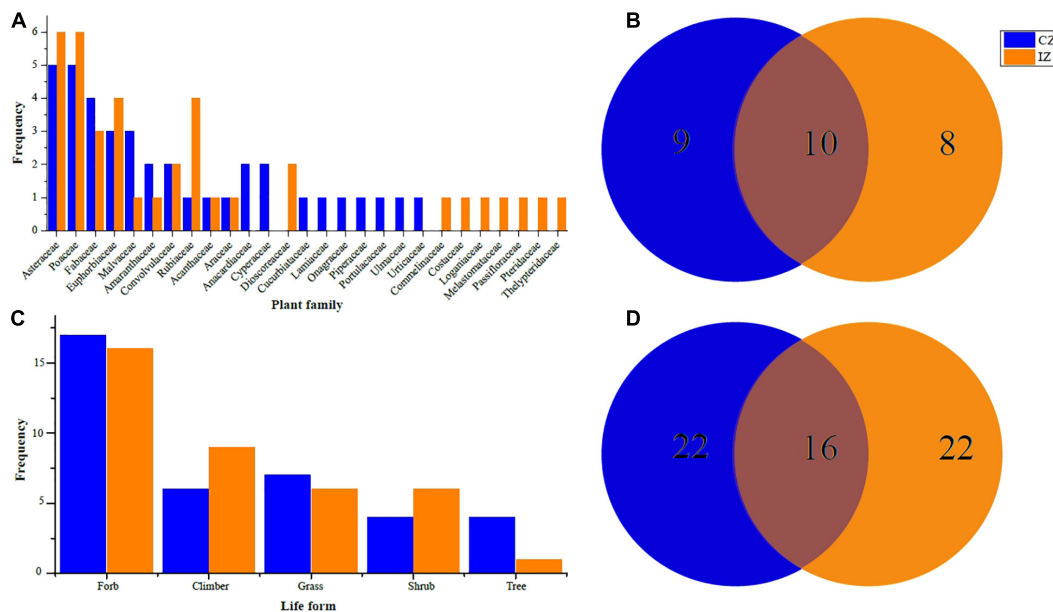


FIGURE 3 | Comparative Species distribution of the study area. **(A)** Family, **(B)** number of unique families, **(C)** life form, and **(D)** the number of unique species.

CZ were as follows: Dominance index (0.36), Simpson (0.64), Shannon—Wiener's (1.25), Margalef (1.13), Evenness (0.70), and equitability values (0.77) (Table 3).

The floral composition also included agricultural species [*Abelmoschus esculentus* (L.) Moench., *Colocasia esculenta* (L.)

Schott., *Dioscorea* sp., *Manihot esculenta* Crantz]. The frequently encountered species outside the quadrat were *Anacardium occidentale* L., *Ficus* Tourn. ex L. sp. and *Lantana camara* L. in the CZ and *Cyperus* L. sp. and *Hyptis suaveolens* (L.) Poit. in the IZ.

TABLE 2 | Species diversity, occurrence, and conservation status in the study area.

S/N	Family	Species	Life-form	IZ				CZ	IUCN status
				F	R.F (%)	D (M ²)	R.D (%)		
1	Acanthaceae Juss.	<i>Asystasia gangetica</i> (L.) T. Anderson	Forb	11.11	1.45	0.04	1.47	✓	NA
2	Amaranthaceae Juss.	<i>Alternanthera sessilis</i> L.	Forb	11.11	1.45	0.04	1.47	–	LC
		<i>Cyathula prostrata</i> (L.) Blume	Forb	–	–	–	–	✓	NA
		<i>Gomphrena celosioides</i> Mart.	Forb	–	–	–	–	✓	NA
3	Anacardiaceae (R.Br) Lindl.	<i>Mangifera indica</i> L.	Tree	–	–	–	–	✓	DD
		<i>Spondias mombin</i> Jacq.	Tree	–	–	–	–	✓	NA
4	Araceae Juss.	<i>Colocasia esculenta</i> (L.) Schott.	Forb	11.11	1.45	0.04	1.47	✓	LC
5	Asteraceae Bercht. and J. Presl	<i>Ageratum conyzoides</i> (Mill.) M. Sharma	Forb	77.78	10.14	0.28	10.29	✓	NA
		<i>Chromolaena odorata</i> (L.) R. M. King and H. Rob.	Shrub	55.56	7.25	0.2	7.35	✓	NA
		<i>Emilia coccinea</i> (Sims) G. Don	Forb	22.22	2.90	0.08	2.94	✓	NA
		<i>Synedrella nodiflora</i> (L.) Gaertn.	Forb	11.11	1.45	0.04	1.47	✓	NA
		<i>Tridax procumbens</i> L.	Forb	11.11	1.45	0.04	1.47	–	NA
		<i>Vernonia cinerea</i> L.	Forb	–	–	–	–	✓	NA
		<i>Aspilia africana</i> (Pers.) C.D. Adams	Forb	22.22	2.90	0.08	2.94	–	NA
6	Commelinaceae Mirb.	<i>Commelina diffusa</i> Burm.f.	Forb	11.11	1.45	0.04	1.47	–	LC
7	Convolvulaceae Juss.	<i>Ipomoea cairica</i> (L.) Sweet	Climber	11.11	1.45	0.04	1.47	✓	NA
		<i>Ipomoea hederifolia</i> L.	Climber	–	–	–	–	✓	NA
		<i>Ipomoea involucreta</i> Beauv.	Climber	33.33	4.35	0.12	4.41	–	NA
8	Costaceae Nakai	<i>Costus afer</i> Ker Gawl.	Forb	11.11	1.45	0.04	1.47	–	NA
9	Cucurbitaceae Juss.	<i>Luffa cylindrica</i> M. Roem.	Climber	–	–	–	–	✓	NA
10	Cyperaceae Juss.	<i>Kyllinga erecta</i> Schumach.	Sedge	–	–	–	–	✓	NA
		<i>Mariscus alternifolius</i> Vahl	Sedge	–	–	–	–	✓	NA
11	Dioscoreaceae R.Br.	<i>Dioscorea alata</i> L.	Climber	11.11	1.45	0.04	1.47	–	NA
		<i>Dioscorea</i> sp.	Climber	11.11	1.45	0.04	1.47	–	NA
12	Euphorbiaceae Juss.	<i>Alchornea cordifolia</i> (Schumach. and Thonn.) Müll.Arg.	Shrub	22.22	2.90	0.08	2.94	–	NA
		<i>Euphorbia heterophylla</i> L.	Forb	–	–	–	–	✓	NA
		<i>Euphorbia hirta</i> L.	Forb	–	–	–	–	✓	NA
		<i>Manihot esculenta</i> Crantz	Shrub	22.22	2.90	0.08	2.94	✓	NA
		<i>Phyllanthus amarus</i> Schumach. and Thonn.	Shrub	11.11	1.45	0.04	1.47	–	NA
		<i>Phyllanthus muellerianus</i> (Kuntze) Exell	Shrub	11.11	1.45	0.04	1.47	–	NA
		<i>Peltophorum pterocarpum</i> (DC.) K. Heyne	Tree	–	–	–	–	✓	NA
13	Fabaceae Lindl.	<i>Calopogonium mucunoides</i> Desv.	Climber	55.56	7.25	0.2	7.35	✓	NA
		<i>Centrosema pubescens</i> Benth.	Climber	11.11	1.45	0.04	1.47	–	NA
		<i>Desmodium tortuosum</i> (Sw.) DC.	Climber	–	–	–	–	✓	NA
		<i>Desmodium triflorum</i> (L.) DC.	Climber	11.11	1.45	0.04	1.47	✓	LC
		<i>Solenostemon monostachyus</i> (P. Beauv.) Briq.	Forb	–	–	–	–	✓	NA
14	Lamiaceae Martinov	<i>Solenostemon monostachyus</i> (P. Beauv.) Briq.	Forb	–	–	–	–	✓	NA
15	Loganiaceae R.Br. ex Mart.	<i>Anthocleista vogelii</i> Planch.	Tree	22.22	2.90	0.08	2.94	–	NA
16	Malvaceae Juss.	<i>Abelmoschus esculentus</i> (L.) Moench	Shrub	–	–	–	–	✓	NA

(Continued)

TABLE 2 | Continued

S/N	Family	Species	Life-form	IZ				CZ	IUCN status
				F	R.F (%)	D (M ²)	R.D (%)		
		<i>Sida acuta</i> Burm.fil.	Forb	–	–	–	–	✓	NA
		<i>Urena lobata</i> L.	Shrub	22.22	2.90	0.08	2.94	✓	NA
17	Melastomataceae Juss.	<i>Tristemma hirtum</i> P. Beauv.	Forb	11.11	1.45	0.04	1.47	–	NA
18	Onagraceae Juss.	<i>Ludwigia</i> sp.	Forb	–	–	–	–	✓	LC
19	Passifloraceae Juss. ex Roussel	<i>Adenia cissampeloides</i> (Planch. ex Hook.) Harms	Climber	11.11	1.45	0.04	1.47	–	NA
20	Piperaceae Giseke	<i>Peperomia pellucida</i> (L.) Kunth	Forb	–	–	–	–	✓	NA
21	Poaceae Barnhart	<i>Axonopus compressus</i> (Sw.) P. Beauv.	Grass	33.33	4.35	0.12	4.41	✓	NA
		<i>Brachiaria deflexa</i> (Schumach.) C.E. Hubb. ex Robyns	Grass	11.11	1.45	0.04	1.47	✓	NA
		<i>Eleusine indica</i> (L.) Gaertn.	Grass	–	–	–	–	✓	LC
		<i>Imperata cylindrica</i> (L.) Raeusch.	Grass	11.11	1.45	0.04	1.47	–	NA
		<i>Panicum maximum</i> Jacq.	Grass	66.67	8.70	0.24	8.82	✓	NA
		<i>Pennisetum purpureum</i> Schumach.	Grass	11.11	1.45	0.04	1.47	–	NA
		<i>Setaria barbata</i> (Lam.) Kunth	Grass	11.11	1.45	0.04	1.47	✓	NA
22	Portulacaceae Juss.	<i>Talinum triangulare</i> (Jacq.) Willd.	Forb	–	–	–	–	✓	NA
23	Pteridaceae E.D.M.Kirchn	<i>Adiantum</i> sp.	Fern	11.11	1.45	0.04	1.47	–	NA
24	Rubiaceae Juss.	<i>Borreria ocymoides</i> (Burm.f.) DC.	Forb	33.33	4.35	0.12	4.41	–	NA
		<i>Borreria verticillata</i> (L.) G. Mey.	Forb	11.11	1.45	0.04	1.47	–	NA
		<i>Diodia scandens</i> Sw.	Climber	11.11	1.45	0.04	1.47	–	NA
		<i>Oldenlandia corymbosa</i> L.	Forb	11.11	1.45	0.04	1.47	✓	LC
25	Thelypteridaceae Ching ex Pic. Serm.	<i>Cyclosorus</i> sp.	Fern	11.11	1.45	0.04	1.47	–	NA
26	Ulmaceae Mirb.	<i>Trema orientalis</i> (L.) Bl.	Tree	–	–	–	–	✓	NA
27	Urticaceae Juss.	<i>Laportea aestuans</i> (L.) Gaud.	Forb	–	–	–	–	✓	NA

F, Frequency; R.F, Relative frequency; D, Density; R.D, Relative density; –, Absent, ✓, Present, NA, Not Assessed, DD, Data Deficient, LC, Least Concern.

TABLE 3 | Species index table for the sampled points with in the studied area.

Sampled points	Incident zone							Pooled control zone
	1	2	3	4	5	6	7	
Dominance_D	0.184	0.088	0.09511	0.5017	0.3841	0.2779	0.28	0.3581
Simpson_1-D	0.816	0.912	0.9049	0.4983	0.6159	0.7221	0.72	0.6419
Shannon_H	1.885	2.66	2.521	0.6914	1.115	1.335	1.332	1.247
Margalef	2.203	4.346	3.463	0.353	1.059	0.9568	0.932	1.134
Evenness_eH/S	0.8237	0.794	0.8297	0.9983	0.7624	0.9499	0.9473	0.6959
Equitability_J	0.9067	0.9202	0.9311	0.9975	0.8044	0.9629	0.961	0.7747

Conservation Status of the Species in the Study Area

The conservation status of the following species based on the IUCN global assessment, *Alternanthera sessilis* (L.), *Spondias mombin* Jacq., *C. esculenta*, *D. triflorum*, *Eleusine indica* (L.) Gaertn., *O. corymbosa*, *C. diffusa*, *I. cairica*, *K. erecta*, *Alchornea*

cordifolia (Schumach. and Thonn.) Müll.Arg., *Urena lobata* L., Gaertn, *Imperata cylindrica* (L.) Raeusch., *Anthocleista vogelii* Planch., *Pennisetum purpureum* Schumach, *Trema orientalis* (L.) Bl., and the Pan-Africa assessment for *A. conyzoides* was LC. *Mangifera indica* L. and *M. esculenta* were DD, while others were NE for those not accessed or ND for those not identified to the species level (Table 2).

DISCUSSION

The floristic composition of the sampled area was examined based on the impact of coal mining, farming, and climate change (precipitation). For instance, the annual rainfall for Enugu in 2016 (NIMET, 2017) was more than the average quantity recorded in the past (Ofomata, 1965; Ezeigbo and Ezeanyim, 1993; NIMET, 2013; Okwu-Delunzu et al., 2018). The increase in annual rainfall might have contributed to species diversity within the Coal Camp. Thus, it was not surprising that plants in the inventory were characteristic of forests, uplands, flooded and wet places.

The observed change in vegetation from tropical rain forest to savannah grasslands due to anthropogenic activities had also been reported by Ezeigbo and Ezeanyim (1993). The registered cultivated species are due to their propagation by the human communities, and their management is still carried out for consumption and income. This practice could also have contributed to the disruption of the natural succession within the study area.

The species distribution on the coal dumpsite (IZ) was compared with that from an area presumed free of visible coal discards (CZ) but not pristine. Since we had no access to pristine vegetation, reference was made to a technical report detailing a field survey of Abor (Environmental and Social Impact Assessment [ESIA], 2016), about 15 km away, which we adopted as baseline data for use as pre-mining information on the vegetation. We found similarities in the species composition between the reference survey and our study area (*A. vogelii*, *A. cordifolia*, *S. mombin*, *A. africana*, *C. odorata*, *A. gangetica*, and *E. indica*). However, our study failed to record some tree species (*Parkia biglobosa*, *Khaya senegalensis*, *Baphia nitida*, and *Daniellia oliveri*). Reasons for this is due to fewer anthropogenic activities and semi-tropical rainforest vegetation type (Environmental and Social Impact Assessment [ESIA], 2016).

The unequal sampling frequency between the IZ and CZ due to patchiness impeded the comparison of species richness and diversity for both zones. Instead, presence and absence were used (Table 2). From our study, both areas shared moderately similar species composition (family 37.04% and species 26.67%), contrasting previous studies where species diversity was higher in the pre-mining/unpolluted sites than in the polluted/reclamation sites (Komara et al., 2016; Hapsari et al., 2020). On the other hand, life forms such as forbs, grasses and trees in our CZ were higher than the polluted study area. The observed distribution patterns between both zones are driven by similar edaphoclimatic and physiographic features; the observed heterogeneity in species distribution within the IZ could have been due to the post-impact of coal mining activities and human activities. This may underlie the highest species diversity observed in this location.

The dominance of the families Asteraceae and Poaceae (Table 2 and Figure 3A) in the revegetation of the coal dumpsite conform with other studies. For instance, they have been reported as the principal colonizers in a Kosovo coal ash dump site (Mustafa et al., 2012) and a Moravia dumpsite in Colombia (Sánchez-Pinzón et al., 2010). Ekka and Behera (2011) also noted

that Poaceae was the prominent family in revegetation of 3–9-year-old dump sites post-coal mining. On the other hand, *A. conyzoides*, *P. maximum*, *C. mucunoides* and *C. odorata* were the most commonly found species in the study area. In line with previous studies, these species have been reported in various coal mining sites (Sánchez-Pinzón et al., 2010; Komara et al., 2016; Novianti et al., 2017; Yusuf and Arisoelaningsih, 2017; Igwenagu et al., 2019; Hapsari et al., 2020). The frequent occurrence of these species in polluted sites might be due to their invasive nature (Borokini, 2011). Additionally, these species seem to have a highly competitive rate, ease of seed germination, and high resistance to varying environmental and soil conditions.

Our evaluation of species composition within the study area exposed the impact of previous mining activities and their waste on vegetation structure. Data from the IUCN Assessment revealed that most of the species being NE and DD were not in the conservation status spectrum, and the remnant quarter belonged to the Lower risk category of LC. there were no Threatened species within the sampled area., Therefore, there were no endangered, vulnerable or threatened species within the study area except for the trees. Even so, an assessment scheme needs to be established to monitor the remnant biodiversity within the study area for posterity.

The Economic Tree Species Present in the CZ Were *M. indica*, and *A. occidentale*. Food Crops encountered during the study include *C. esculenta* (IZ and CZ), *Dioscorea* spp. (IZ), *M. esculenta* (IZ and CZ). In agreement with previous studies, one or multiple of these species (*C. esculenta* and *M. esculenta*) have been found in some coal mine sites (Panda et al., 2011; Komara et al., 2016; Arshi, 2017; Igwenagu et al., 2019). Previously, some economic tree species that were logged from this ecological zone include *Canarium schweinfurtii* (black pear), *Pentaclethra macrophylla* (oil bean), *Garcinia kola* (bitter kola), *Vitex doniana* (black plum), *Milicia excelsa* (Iroko) *Khaya ivorensis* (mahogany) *Nauclea diderrichii* (Opepe) (Ogbonna et al., 2015). These species have disappeared as none was present in this current study. Anthropogenic activities such as overexploitation and habitat fragmentation and might have influenced the forest structure reducing the trees to mostly forbs. Those species would have been exploited because of their peculiar wood qualities (*M. excelsa*, *K. ivorensis*) and medicinal uses (*P. macrophylla*).

Revegetation for conservation must be mandatory for the maintenance of the ecosystem and future use of the area. There is a need to remove the invasive species as they could hinder profitable species (Yusuf and Arisoelaningsih, 2017).

CONCLUSION

Our study evaluated the biodiversity assessment of a defunct coal mine site (IZ) and found marginal differences between its species composition and those within the CZ. This may be due to the fact that mining had ceased entirely at this location about 15 years ago. Post-mining activities (e.g., farming and community development projects) and the plasticity of the species surviving harsh climatic and environmental conditions, could explain the species population dynamics within the study

area. Nevertheless, we propose future studies to investigate the rhizospheric microbial communities and their metabolic roles in coal degradation. This study could provide insights into the sustenance of plant growth in coal polluted environments. Our findings iterated the continuous decline of biodiversity in the Nigerian ecosystem following the irrational use of the resources. Although the study site might not be considered a high conservation priority area, a habitat restoration scheme for maintaining the ecosystem is recommended. Lastly, from the findings of this study, it would be helpful to form a guideline for future conservation management of the study area.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

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AUTHOR CONTRIBUTIONS

AO participated in the collection of experimental data for floral distribution, data analysis, and interpretation. EI participated in the conception and design of floral distribution experiments. OO participated in the conception and design of floral distribution, collection of experimental data, data analysis, and interpretation. IN initiated the research idea, participated in the conception, design, data analysis, and interpretation. All authors participated in writing and approved the final manuscript.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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