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Investigation of Floristic Composition, Species Abundance and Diversity of Plant Species in Akwuke and Iva Mining Sites, Enugu State, Nigeria

***Ogbonna, P.C., Nzegbule, E.C. and Okorie, P.E.**
Department of Environmental Management and Toxicology, Michael Okpara University of Agriculture, Umudike, P.M.B. 7267 Umuahia, Abia State, Nigeria.
*ogbonna_princewill@yahoo.com

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ABSTRACT

Complete enumeration of plants above 30 cm in height was carried out at Akwuke and Iva mining sites and a control plot in Enugu State, Nigeria. For plant diversity, a total of 144, 208 and 340 tree species, and 36, 32 and 84 shrubs species, and 8, 18 and 12 climbers' species as well as 104, 144 and 72 herbs/graminoids were represented in Akwuke, Iva and control sites, respectively. Menhinick's species abundance index for tree and shrub species were high at Iva and Akwuke respectively and also for herbs/graminoids at the control plot. Simpson's species diversity index for shrub species was high at the Iva mining site as compared to that of the control plot and Akwuke mining site. However, the Simpson's species diversity index for trees did not differ at the mining sites but was low at the control plot. The results show that the control plot had undergone degradation as indicated by the presence of Andropogon gayanus and Hyparrhenia involucrate. However, if left undisturbed, it has the potential of regeneration back to its original state because of its tree species composition. The increase in herbaceous species at the mining site is an indication of primary regenerative succession that seems to be progressive towards shrubby habit if protected.

1. INTRODUCTION

Coal mining is an anthropogenic activity that involves extraction of coal mineral from coal face and the process alters the landscape (Ogbonna *et al*., 2018a). The geologic material removed from above a mineral deposit during mining is called spoil and orphan spoil (i.e. devoid of plants) contain high concentration of salts or acid-forming materials, stones, coarse sand that hinder or impede succession or revegetation at mining sites (Ogle and Redente, 1988). Succession is a natural process of plant community development on mine spoils and plant regeneration of abandoned mine spoils is a developmental process that is essential for biodiversity maintenance and sustainability of environmental health. Resuscitating mining sites (mine spoils) with plants is difficult because it is lacking organic matter, *inter alia*, macronutrients like nitrogen (N) and phosphorus (P), calcium (Ca), magnesium (Mg), and potassium (K) (Hazarika *et al*., 2006). In addition, acid mine drainage (AMD) at mining sites decreases microbial population as well as impede root growth and development of plants, thus, affecting biomass production and nutrient cycling (Sarma, 2002; Ogbonna *et al*., 2019a). Notwithstanding this, plant species occur naturally on the barren mined land after a period of time from the origination of dump, but succession of plant species under such situation proceeds at a much slower rate (Bradshaw and Chadwick 1980; Roberts *et al*., 1981; Singh and Jha 1992; Hazarika *et al*., 2006).

Measures of vegetation structure provide information on habitat suitability, ecosystem productivity and successional pathways (Silver *et al*., 2004; Wang *et al*., 2004) while species diversity provide information on susceptibility to invasion and trophic structures (Nichols and Nichols 2003; Sarma *et al*., 2010). Enugu State is naturally endowed with tropical rainforest (Keay, 1959) but it has significantly depleted mainly as a result of human activities like agriculture (Ezeigbo and Ezeanyim, 1993), logging, nomadic activities of cattle rearers from the north, mining (Ogbonna *et al*., 2012; Ogbonna *et al*., 2015), rapid increase in human population (Ogbonna *et al*., 2018b) and demand for sawn timbers (wood) by the colonial masters. Enugu State has large deposits of bituminous coal, estimated at 1.5 million tons (Diala, 1984). Nigerian Coal Corporation started mining in 1916 at Enugu Coalfield, and in October 1977, their operations became mechanized (Asogwa, 1988; Onwukeme, 1995). Coal mining is a major land-use particularly in Enugu State, Nigeria where a good number of indigenes are employed in the activity causing unwanted destruction and deterioration of the mining environment. The metal concentration of coal in Enugu State is relatively lower than that of China and United States of America (USA) and the ash content is low (Ogbonna, 2014).

Although coal mining in this area has recently slowed down because of the shift to crude oil as energy source, the spoils and waste still exist and biodiversity regeneration is progressing. There is no doubt that coal mining so far has contributed to defining the pattern of plant community development in the area due to the nature of the mineral, mining procedure as well as the processing activities of the coal (Ogbonna *et al*., 2015; Ogbonna *et al*., 2019a; Ogbonna *et al*., 2019b). Therefore, there is need to track the evolving changes in the areas engaged in coal mining especially with regards to plant community reactions. Literature search showed that various researches have been carried out on vegetation composition at mining sites in India (Pandey *et al*., 1993; Rai 2002; Sarma *et al*., 2004; Sarma 2005; Barik *et al.,* 2006; Kumar *et al*., 2014), the role of microorganisms in the revegetation of strip-mined land in the western United States (Cundell, 1977), ecology of some mined areas in North Dakota (Wall and Freeman, 1973), re-establishing North Dakota grasslands after mining with emphasis on seasonality and use of natural species (Williamson, 1984), an investigation of soil development on mine spoils, Wyoming (Barker, 1979), plant response and forage quality for controlled grazing on coal mine spoil pastures (DePult and Coenenberg, 1980), establishment of diverse native plant communities on coal surface-mined lands in Montana as influenced by seeding method, mixture and rate in Montana (DePult *et al*., 1980), effects of two years of irrigation on revegetation of coal surface-mined land in southern Montana (DePult *et al*., 1982), soil development and plant succession on 1-to-50 year-old strip mine spoils in southeastern Montana (Schafer and Nielsen, 1979), vegetation development on surface mined land in eastern Montana (Silndelar, 1984), establishment, succession and stability of vegetation on surface mined lands in eastern Montana (Silndelar and Plantenberg, 1978), plant succession on five naturally revegetated strip-mined deposits at Colstrip, Montana (Skllbred, 1979), revegetation studies on coal spoil banks in southwestern Wyoming, Laramie (Jacoby Jr, 1968), supplemental water for establishment of perennial vegetation on strip-mined lands (Ries, 1980) in United States of America, natural revegetation of strip-mined land in the lignite coalfields of southeastern Saskatchewan (Jonescu, 1979) Canada, natural succession on strip-mined lands in northwestern New Mexico (Wagner *et al*., 1978), floristic and diversity trend of regeneration in a quartz dominated quarry impacted site in parts of Umuoke, in Obowo local government area of Imo State, Nigeria (Edwin-Wosu *et al*., 2013), floristic indicators of tropical land use systems: evidence from mining areas in Southwestern Nigeria (Akinbiola *et al*., 2016), effect of mining activities on vegetation composition and nutrient status of forest soil in Benue Cement Company, Benue State, Nigeria (Unanaonwi and Amonum, 2017).

Despite the fairly extensive research, no such work on floristic composition has been carried out at any coal mine site in Nigeria. The works of Edwin-Wosu *et al.* (2003) was carried out at a quartz quarrying site, and the work of Akinbiola *et al.* (2016) was at gold and rock mining site while Unanaonwi and Amonum (2017) was carried out at a limestone mining site and these mining activities were more of artisanal and small scale unlike the mechanized and large scale mining operations that took place at Enugu State, Nigeria. The objective of this study, therefore, was to identify and document naturally occurring trees, shrubs, herbs and graminoids at Akwuke and Iva mine sites. Consequently, this study will provide background information on the floristic composition, species abundance and diversity of plant species at Akwuke and Iva mining sites and serve as a tool for similar study (ies) for other coal mining sites in Nigeria, and aid our governments in policy making while leasing lands or granting licenses to miners in Nigeria.

2. MATERIALS AND METHODS

2.1. Study Area

The study was carried out at Akwuke and Iva mines in Enugu, Enugu State. Enugu has very large deposits of sub-bituminous coal that was extracted mechanically at the underground long wall mine sites at Akwuke and Iva. Enugu lies within latitude 6^o 23' and 6^o 26' N and longitude 7^o 27' and 7^o 30' E (Ogbonna *et al.*, 2018c). The mean monthly temperature lies between 27 and 29 °C (Ekere and Ukoha, 2013) and it experiences two seasons: rainy season which begins from April and ends October and the dry season begins from November and ends March. The natural vegetation is tropical rain forest type but has significantly changed over time to guinea savannah due to human activities such as farming (Ezeigbo and Ezeanyim, 1993), nomadism and exploitation of fuel wood (Ogbonna *et al.*, 2015). The major streams/rivers in Enugu include the Ekulu, Ogbete and Nyaba rivers.

2.2. Determination of Plant Species Abundance and Diversity

In the identification and enumeration of plant species, all floral species within the two mined and the unmined sites (control plot) were considered. Thus, 50 m × 50 m land areas (plots) which cover both the inner and peripheral parts of the mined and unmined sites were used for the identification and enumeration of plant species. Plant species above 30 cm in height found within the 50 m x 50 m plots were identified and subsequently enumerated. Identification of plants species was made in the field while specimen samples of those that could not be identified were collected with a secateur, clearly labeled, placed in plant press and subsequently taken to the Herbarium Laboratory of the Department of Forestry and Environmental Management of Michael Okpara University of Agriculture, Umudike, where they were properly identified by the Taxonomists. The species abundance of the mined and unmined sites was determined by the Menhinick's Species abundance/richness index.

$$D = \frac{S}{\sqrt{N}} \tag{1}$$

Where S = number of species and N = total number of individuals

The Simpson's Species diversity index was used to calculate species diversity of the sampled plots using Equation 2.

$$D = \sum_{i=1}^{s} p_i^2 \tag{2}$$

Where $p_i^2 = \left[\frac{N_i}{N_r}\right]^2$ relative abundance of the ith species

Ni = number of the ith species and Nr = total number of individuals.

3. RESULTS AND DISCUSSION

The floristic composition, species abundance and diversity of plant species enumerated at Akwuke mine, Iva mine and a control site are summarized in Tables 1 to 3. The results indicate that there were variations in the composition of plant in the mined (Akwuke and Iva) and control sites. Indeed, a total of 144 individual plants belonging to 10 families were recorded for Akwuke mine; 208 individual plants belonging to 11 families were recorded for Iva mine while 340 individual plants belonging to 9 families were observed in the unmined (control) site, respectively. Three shrubs species belonging to 3 families were recorded for Akwuke mine, 1 shrub species belonging to 1 family was recorded for Iva mine while 3 shrubs species belonging to 3 families were recorded for the control site, respectively. Indeed, 1 climber species belonging to 1 family was recorded for Akwuke mine, 2 climber species belonging to 2 families was recorded for Iva mine site while 1 climber species belonging to 1 family was recorded for the control site. Herbs, including graminoids were represented by 6, 8, and 7 species from 4, 6, and 5 families in Akwuke, Iva, and the unmined site, respectively. Suitable microsites, weather and availability of seeds are major factors that determine the success of seedling germination (Eriksson and Ehrlen, 1992; Eriksson, 2000). Seed availability is in turn influenced by such factors as seed production, dispersal and seed predation (Jensen, 1985; Eriksson, 1995).

A total of 26 families were enumerated in the study (Table 1-3). Twelve families: Leguminosae (*Daniellia oliveri, Parkia biglobosa, Albizia ferruginea, Dialium guinense* and *Baphia nitida*), Myrtaceae (*Eugenia kerstingii, Syzygium guineense*), Ochnaceae (*Lophira lanceolata*), Euphorbiaceae (*Alchornea cordifolia, Manihot esculenta*), Anacardiaceae (*Mangifera indica, Spondias mombin*), Irvingiaceae (*Irvingia gabonensis* var. *excelsa*), Icacinaceae (*Icacina trichantha)*, Arecaceae (*Eremospatha laurentii* De Wild), Poaceae (*Anthephora ampullace, Hyparrhenia involucrate, Andropogon gayanus*), Rubiaceae (*Fadogia cienkowskii*), Oleandraceae (*Nephrolepis biserrata*), Orchidaceae (*Eulophia gracilis*) were represented both in the mined and unmined sites. Most of the species mentioned above are dispersed through explosive mechanisms vis-à-vis some animals that consume fruits which are features that aid colonization by plants species. The presence of plants in the Poaceae family indicates the successional stage of the plant community regeneration as pioneer plant species (Odiwe *et al*., 2012) while the presence of *M. esculenta* at the mine and control sites indicated human interference of the ecosystem. The family Acanthaceae (*Asystasia gangetica*) was recorded only in the unmined site. Farming operations or activities such as land clearing, bush burning, and weeding may have affected plant species diversity in the unmined site. Nigeria has one of the world's highest rate of deforestation of primary forests, where more than 50% of such forests have been lost in the past decades through unsustainable logging, agriculture, and fuel wood collection (FAO, 2004). Deforestation via human activities has intensively threatened, depleted, and endangered biodiversity of the forest ecosystem (Oluyemi *et al*., 2014). The families Bignoniaceae (*Newbouldia laevis*), Myrtaceae (*Psidium guajava*), Burseraceae (*Dacryodes edulis*) and Connoraceae (*Byrsocarpus coccineus*) were recorded only in Akwuke mine while the families Verbenaceae (*Vitex doniana, Gmelina arborea*), Anacardiaceae (*Spondias mombin*), Lauraceae (*Persea americana*), Sterculiaceae (*Cola lepidota*), Gnetaceae (*Gnetum africana*), and Zingiberaceae (*Aframomum danielli*) were recorded only in Iva mine site, respectively. The presence of fruit trees in the mined sites may be associated with mine workers that carried these fruits that served as refreshment and possible source of vitamins and energy. The mine workers might have discarded the seeds of these fruits around the mining sites after they consumed the exocarp. In this study, a total of 144, 208, and 340 tree species; 36, 32, and 84 shrub species; 8, 8, and 12 climber species as well as 104, 144, and 72 herbs, including graminoids were recorded for Akwuke mine site, Iva mine site, and the control site, respectively. There was reduction in the total number of plant species regenerated at the mined sites and this may be attributed to vegetation removal, low soil organic matter content/ poor nutrient status, and heavy metal concentration in soil. Mine soils are characterized by poor nutrient status which affects the physiochemical properties of soil. More so, plant tolerance to different metals varies widely (Guilizzoni, 1991) and elevated levels of heavy metals such as Cd, Pb, Ni can be toxic to plants (Steffen, 1990), reduced germination, and alter enzymatic processes and nutrient uptake (Bazzaz *et al*., 1974; Barua and Jana, 1986). Mine spoils constitute very rigid substrata that hardly encourage plant growth and development (Kiranmay, 2005). Soil particles size (Down, 1974) and compaction (Hall, 1957; Richardson, 1975) influence the colonization of plants on overburdens. The unmined site (bush fallow) with 12 families in occurrence had the highest population of plant species with 134 species followed by Iva mine site with 98 species while Akwuke mine site recorded the lowest with 73 plant species in occurrence. The control site could have offered more microsites than Akwuke and Iva mine sites and its (control) proximity to source of viable propagules may have accounted for the highest population of plant species. Formation of more microsites and proximity to a source of viable propagules such as existing mature plant communities is an advantage to be considered in regeneration potentials of new species into a site (Spur and Barnes, 1973; Ehrlen and Eriksson, 2000; Sarma, 2002; Ogbonna, 2014). Generally, most of the trees/shrubs/herbs were more in the peripheral zone than in the inner zone of the mined sites.

The abundance and diversity of tree species at the mined and unmined sites in Enugu, Nigeria is summarized in Table 1. The results indicate that the highest total number of individual plants within the 3 sampled sites occurred at the control site (340 trees in occurrence). Notwithstanding this, the abundance of tree species was highest at Iva mine site (2.77) while the diversity of tree species was higher at Akwuke mine (0.21) and Iva mine (0.21) sites.

Table 1: Species abundance and diversity of trees in coal mine sites in Enugu, Nigeria

			Number of trees ha^{-1}			
			Coal mine sites			
Family	Species	Common Names	Akwuke	Iva	Control	Total
Leguminosae	*Daniellia oliveri (Rolfe)*	Balsam tree	8	4	16	28
	Paekia biglobosa	African locust bean	4	8	24	36
	Albizia ferruginea		-	8	16	24
	Dialium guinense	Tamarind	20	28	68	116
	Baphia nitida	Camwood African Tulip tree	-	4	32	36
Bignoniaceae	*Spathodea companulata*	African Tulip tree	4	-	8	12
	Newbouldia laevis	Tree of life	4	-	-	4
Myrtaceae	*Eugenia kerstingii (Eng.)*		12	8	4	24
	Syzygium guineense	Water pear	4	4	-	8
	Psidium guajava	Guava	4	-	-	4
Moraceae	*Ficus infectoria*	White fig	8	12	-	20
	Milicia excelsa	Iroko	-	4	8	12
Ochnaceae	*Lophira Lanceolata*	Red oak	4	4	8	16
Verbanaceae	*Vitex doniana*	Black plum	-	4	-	4
	Gmelina arborea	Gmelina	-	8	-	8
Euphorbiaceae	*Alchornea cordifolia*	Christmas bush	20	32	64	116
	Manihot esculenta	Cassava	12	12	28	52
Anacardiaceae	*Mangifera indica*	Mango	16	20	24	60
	Spondias mombin	Golden apple	-	4	-	4
Irvingiaceae	*Irvingia gabonensis*	Wild mango	20	16	24	60
Burseraceae	*Dacryodes edulis*	African pear	4	-	-	4
Lauraceae	*Persea americana*	Avocado pear	-	8	-	8
Arecaceae	*Elaeis guinensis*	Oil palm	-	8	16	24
Sterculiaceae	*Cola lepidota*	"Achicha"	-	12	-	12
Total number of individual plants			144	208	340	692
Total number of tree species			15	20	14	24
Menhinick's species abundance index			2.56	2.77	1.52	1.82
Simpson's species diversity index			0.21	0.21	0.11	0.09

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Table 2: Species abundance and diversity of shrubs in coal mine sites in Enugu, Nigeria

Number of shrubs ha^{-1}						
			Coal mine sites			
Family	Species	Common Names	Akwuke	Iva	Control	Total
Acanthaceae	*Asystasia gangetica*	Creeping foxglove	-	-	8	8
Connaraceae	*Byrocarpus coccineus*		8	-	-	8
Annonaceae	*Uvaria chamae*	Finger root	8	-	8	16
Icacinaceae	*Icacina trichantha*	"Ibugo", "Ogwa"	20	32	68	120
Total number of individual plants			36	32	84	152
Total number of shrub species			3	1	3	4
Menhinick's species abundance index			0.50	0.18	0.33	0.32
Simpson's species diversity index			0.41	1.00	0.67	0.64

Table 3: Species abundance and diversity of (a) climbers, and (b) herbs including graminoids in coal mine sites in Enugu, Nigeria

Number of climbers/herbs including graminoids ha^{-1}						
			Coal mine sites			
Family	Species	Common Names	Akwuke	Iva	Control	Total
a. Climbers:			Akwuke	Iva	Control	Total
Aracaceae	*Eremospatha laurentii-De Wild*		8	4	12	24
Gnetaceae	*Gnetum africana*		-	4	-	4
Total number of individual plants			8	8	12	28
Total number of shrub species			1	2	1	2
Menhinick's species abundance index			0.35	0.71	0.29	0.38
Simpson's species diversity index			1.00	0.50	1.00	0.02
b. Herbs, including Graminoids:						
Poaceace	*Anthephor ampullaceae-(Stapf.)*		12	8	20	40
	Hyparrhenia involucrate	Thatching grass	16	8	8	32
	Andropogon gayanus	Gamba grass	52	76	8	136
Rubiaceae	*Fadogia cienkowskii*		4	8	16	28
Oleandraceae	*Nephrolepis biserrata*	Broad sword fern	12	4	4	20
Orchidaceae	*Eulophia gracilis*		8	20	8	36
Fabaceae	*Tephrosia purpurea*	Wild indigo	-	8	8	16
Zingiberaceae	*Aframomum danielli*	Aligator Pepper	-	12	-	12
Total number of individual plants			112	152	84	348
Total number of species			6	8	7	8
Menhinick's species abundance index			0.59	0.67	0.82	0.44
Simpson's species diversity index			0.31	0.32	0.18	0.23

The higher abundance of tree species at Iva mine site may be attributed to the total number of tree species that occurred at Iva mine site (20 tree species) unlike Akwuke mine site and the control site with 15 and 14 tree species in occurrence, respectively. The lower number of abundance of tree species at the control site may be attributed to the age of the bush fallow and collection of staking material for yam production by the rural poor. Other human activities such as slash and burn, weeding and collection of firewood by the rural poor who relied heavily on firewood for cooking due to high price of kerosene and lack of know-how in the use of gas cooker may have accounted for the low number of abundance of tree species at the control site.

Zaku *et al*. (2013) in their review of fuel wood use in Kaduna State reported that majority of the rural people have been using and will continue to use the dried biomass fuels for energy for many years to come. Natural regeneration may be difficult for many forest trees due to hard crust formed on the forest floor by tailings deposit from mining sites. At times the crust is so heavy and hard that young seedlings are stifled or choked (Unanaonwi and Amonum (2017). The total number of individual plants vis-a-vis total number of tree species in this study is 692 and 24, respectively. Similarly, the total species abundance and diversity of tree species are 1.82 and 0.09, respectively. *Dialium guinense* and *Alchornea cordifolia* had the highest number of individual occurrence at Akwuke mine site (20 and 20), Iva mine site (28 and 32), and the control site (68 and 64) followed by *Irvingia gabonensis* and *Mangifera indica* with 20 and 16, 16 and 20, and 24 and 24 while the lowest number of individual occurrence occurred in *Dacryodes edulis, Spondias mombin, Vitex doniana, Psidium guajava*, and *Newbouldia laevis* with only 4 trees each in occurrence.

The abundance and diversity of shrub species at the mined and unmined sites in Enugu, Nigeria is presented in Table 2. The results indicate that the highest total number of individual plants (84 shrubs in occurrence) within the 3 sampled sites occurred at the control site. Notwithstanding this, Akwuke mine site had the highest species abundance (0.50) while the highest diversity of shrubs species (1.00) occurred at Iva mine site. The higher species abundance of shrub species at Akwuke mine site may be attributed to the total number of shrubs species that occurred at Akwuke mine site (3 shrubs species) unlike Iva mine site with 1 shrub species in occurrence. However, the 3 shrubs species in occurrence at the control site did not bring about corresponding higher diversity of shrub species due to the total number of individual plants (shrubs) that occurred at the control site (84 shrubs). The results show that the control plot had undergone serious degradation. Notwithstanding this, the control plot has the inherent ability to regenerate back to its original state because of the composition of tree species enumerated therein. In this study, the total number of individual plants and total number of shrubs species are 152 and 4 while the total species abundance and diversity of shrubs species are 0.32 and 0.64, respectively. *Icacina trichantha* had the highest frequency of occurrence of shrubs species at the 3 sampled sites with 20 at Akwuke mine site, 32 at Iva mine site, and 68 at the control site.

The abundance and diversity of climbers and herbs/graminoids at the mined and unmined sites in Enugu, Nigeria is summarized in Table 3. The results indicate that the highest species abundance of climbers at the 3 sampled sites occurred at Iva mine site (0.71) while the highest species diversity (1.00) occurred at Akwuke mine site. However, Akwuke mine site had higher abundance of climbers (0.35) than the control site (0.29). The higher abundance and diversity of climbers at Iva mine site may be attributed to the total number of species of climbers (2 climber species) in occurrence unlike Akwuke mine site and the control site with 1 shrub species each in occurrence.

The results on herbs, including graminoids indicate that the highest abundance and diversity of herbs/graminoids occurred at the control site (0.82 and 0.18). *Andropogon gayanus* had the highest frequency of occurrence at Akwuke mine site (52 stands), Iva mine site (76 stands), and the control site (8) while *Aframomum danielli* had the lowest occurrence with only 12 stands at Iva mine site. The level of abundance and diversity of trees, shrubs, and herbs/graminoids at the control site indicate its (bush fallow) age and pattern of regeneration. The short fallow period resulting from increase in human population and housing might be implicated for the level of climbers and herbs including graminoids at the control site. Indeed, fallow periods are shortening, while cropping periods lengthen due to increase in population and decline in land available for shifting cultivation (MacDonald, 2003). The herbaceous increase at the mining sites is an indication of a primary regeneration or pattern of succession progressing towards shrubby habitat if left unperturbed.

4. CONCLUSION

Coal mining affected the population of plants at Akwuke and Iva mine sites unlike the control site. Akwuke, Iva and control sites had a total of 300, 400, and 520 plants per ha respectively showing that the control area had significantly higher vegetation. *Alchornea cordifolia* and *Andropogon gayanus* had the highest survival rate among the plant species at the mined sites. In the mined sites, more vegetation was found at Iva (400 plants ha^{-1}) than Akwuke (300 plants ha^{-1}). The study recorded a marked depletion in the abundance and diversity of plant species around mined areas. Restoration should be carried out to enrich the vegetation and improve ecosystem productivity in the mined sites. This will also enhance the population of wildlife in the area by restoring the natural habitats of these species in the area. It is recommended that desire plant species (*Alchornea cordifolia, Andropogon gayanus*) are suitable species to be used to enrich vegetation cover in short time and accumulate biomass rapidly be introduced at the mined sites. This will help to improve soil organic matter status which will bind the soil and the heavy metals. It will also enhance the population growth of soil organisms' in the mined sites.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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