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Effect of the 20km Larfarge Africa PLC road construction/abandonment on soil properties, along Odukpani/Akamkpa road segments, cross river state, Nigeria

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Abstract
In this paper, the effect of road construction/abandonment along Akamkpa-Odukpani segments of Cross Rivers State Nigeria was studied. Purposive sampling was employed in delineating only areas which cut across the length and breadth of the abandoned road project within the study area. These areas included: Abiati, Oberekae, Etankpini and Mbat-Odukpani. Thereafter, the systematic (line transect) was employed to establish quadrat of 10 x 180m, which had 18 quadrats of 10 x 10m. After the 18 quadrats had been established along environmental gradient (abandoned road on both sides), simple random sampling technique was then applied to select 10 quadrats from which soil parameters were obtained. From each plot, soil sample were gotten at predetermined depths at 0–15 cm and 15–30cm of the soil, representing the top and the subsoil layers through a soil auger. Therefore, 20 soil samples were collected in total for the analysis of 15 physico-chemical and 8 heavy metal parameters. From the analysis; it was observed that the soil pH at the surface level across the entire area had a mean of 6.3 with a range of 4.96-6.89. The test of study hypothesis using principal components analysis (PCA) shows that; the soil components are surface ECEC (0.927), surface clay (-0.839), surface sand (0.821) and surface H^+ (0.818). The result in Table 5 therefore shows that topsoil ECEC, subsoil exchangeable bases, topsoil exchangeable bases, subsoil Nitrogen, topsoil aluminium, subsoil clay/sand, subsoil base saturation and topsoil phosphorus are seriously impacted upon by road construction activities. In conclusion, the study identified impacts relating to the construction and abandonment of the 20km road as significant and mostly negative. However, the study recommends that the abandoned road should be completed with sustainable actions taken to manage the negative impacts observed.

Keywords: Road construction, abandonment, soil properties

Introduction

Roads are familiar and widespread landscape feature that make possible the transportation of people, goods and services among places also create way to other way inaccessible places. This was the idea behind the construction of 20 km road in 2010 by Lafarge Africa PLC to facilitate the distribution of its product (cement) across Cross River State. Lafarge Africa Plc, formerly known as United Cement Company Limited is a cement manufacturing company primarily concerned with the manufacture and sale of different brands of cement. To achieve more effective cement evacuation operations as well as keying into the Cross River State government's master plan of the time (1999 – 2007), the 20 km highway was conceived.

The construction of the 20 kilometers (km) highway through the Akamkpa – Odukpani axis of Cross River State was amongst other intentions to open up a relatively pristine area which the Cross River State government of the time intended for development into an Industrial area. The 20 km highway was to cut across the industrial area and quicken the growth and development of the area. In 2010, Lafarge Africa (then United Cement Co. Ltd) commenced the road construction of its 20 km cement evacuation road. The road alignment is a stretch commencing a few kilometres from Odukapni junction in Odukpani Local Government Area, through few village communities and all the way to the Lafarge Cement factory situated along the Calabar – Ekang highway, in the Mfamosing axis of Akamkpa Local Government Area. The road terminates at the entrance gate axis of the cement plant.

Though, constructed roads provide key social and economic functions and services to human societies including flow of materials and information, transportation and cultural exchange. At the same time, they generate a wide range of adverse ecological consequences (ecosystem degradation through pollution and dumping of toxic substances, habitat destruction, landscape fragmentation and species extinction) through edge effects, and landscape segmentation (Feng, Liu, Jing, Zhu, Yan, Jiang, Liu, Lu, Ning, Wang, Li & Jia, 2021). Road construction activities are also known to have both direct and indirect loss in forest ecosystem especially in relatively pristine ecosystems (Coffin, 2010).

Road construction activities result in the loss of forest cover and subsequently decline in soil fertility. Road construction activities also bring about changes in soil quality, alter flows of energy and result in abrupt changes in species compositions among other effects (Mmolawa, Likuku, & Gaboutloeloe, 2011). Road construction causes soil compaction on the road itself and on adjacent areas as a result of road construction activities. Soil compaction inhibits ecological succession on roadsides, in that increased compaction suppresses plant growth as well as cause changes in soil quality (Iwara, Gani, Adeyemi, & Ewa, 2013). Roadside plants and soils exercise a positive influence on the climate by helping in carbon sequestration, thereby regulating the temperature of roadside ecosystem. Among the numerous environmental factors that determine flora distribution, soil remains intrinsic because it provides nutrients, moisture and anchorage to the plants. Therefore, soil has been reported as the predominant ecological factor that affects the distribution of plan (Akbar, Hale, Sera, & Ashraf, 2012) [1]. Thus, understanding roadside soil properties that are influenced by road construction activities can serve as a basis for formulating conservation-based management strategies as well as provide necessary information for carrying out ecological restoration attempts after road construction (Spooner, 2013) [14]. Hence, the research paper examined the effect of road construction/abandonment along Odukpani/Akamkpa road segments of Cross River State being an agrarian Local Government areas since no studies in the literature has ever captured this region.

Materials and methods

Study area

The study area cut across two local government areas of Akamkpa and Odukpani. Akamkpa Local Government Area is located roughly between latitudes $5^{0}00^{1}$N to $5^{0}48^{1}$N and longitudes $8^{0}12^{1}$E to $9^{0}00^{1}$Eof the equator. The local government lies within the Central Senatorial District and had been created in 1976. It has a land mass of 4,300 square kilometres, and its surrounded by Odukpani and Akpabuyo Local Government Areas to the west and south, Biase and Yakurr Local Government Areas to the north west, Ikom and Etung Local Government Areas to the north, also the Republic of Cameroon to the East. On the other hand, Odukpani is a local government area in Cross River State, Nigeria and it rests amid latitude 5°4'52.46"N also longitude 8°20'59.7"E also has a promotion approximately 413ft. It's bounded by Akamkpa Local Government Area in the North, Calabar Municipal in the South, to the west by AkwaIbom State and to the East by Akamkpa. The area is largely populated by the Efik people.

Akamkpa and Odukpani Local Government Areas are located in the rainforest zone and share similar climatic conditions with the Southern part of the state. The yearly rainfall is not less than 2000 mm with peak periods observed between the months of July and September. The relative humidity of the area is between 79 % and 87 % daily. This means that the area is very humid. According to Bisong and Mfon (2006) the annual rainfall ranges from 2,500 mm to 3,000 mm and the temperature is between 2 ºC to 2 ºC in January, but in July it rises above 30ºC. The vegetation of Akamkpa and Odukpani local Government Areas are ever green tropical rainforest which is regarded to be the final strangehold of tropical rainforest in Nigeria (Yaro, 2015). The lands of Akamkpa and Odukpani Local Government Areas are gotten after the basement complex rocks consisting of granite gneiss. Basement complex rocks are seen to happen at Oban and Obudu parts of Cross River State of Nigeria. Akamkpa Local Government Area has a population of 149,705 with the projected population of about 200,100 in 2016 according to 2006 national population census. On the other hand, there is a population figure of 192,884 in Odukpani (2006 National Population Figure). There is also a projection of 257,800 people as a projected number in 2016 projection.

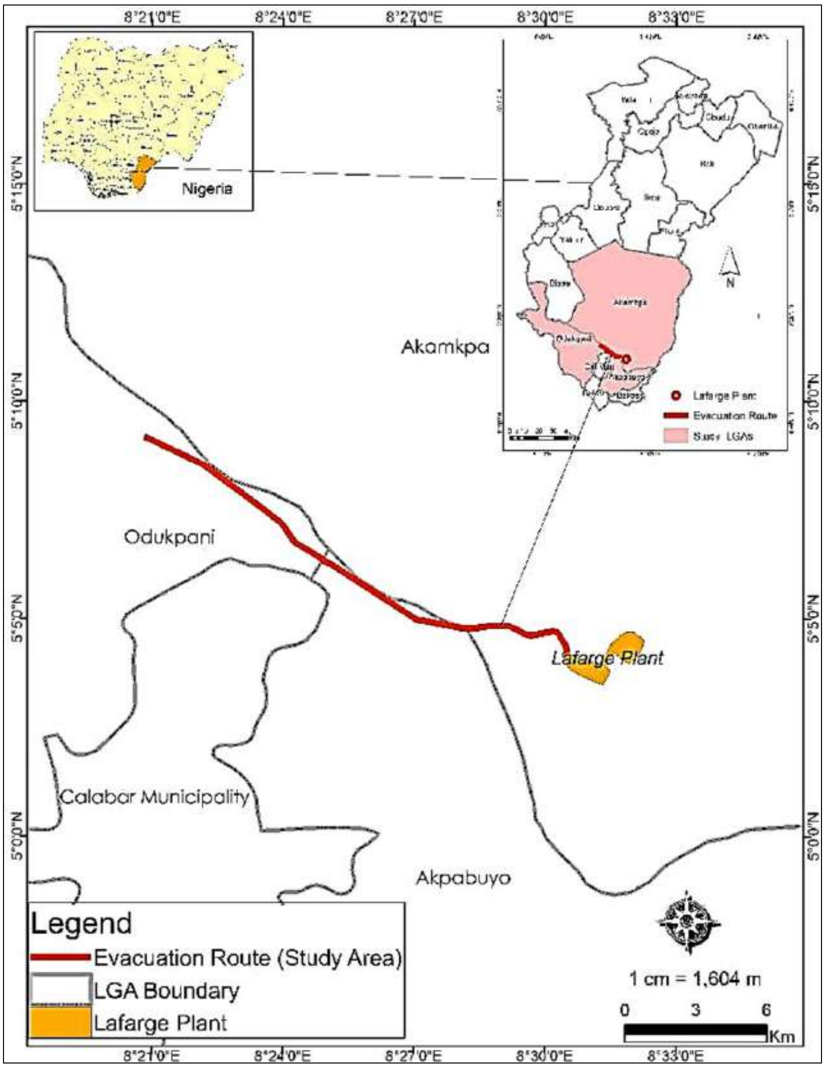

Fig 1: Cross River State showing the two Local Government Areas that cut across the abandoned road

Methods of study

The purposive, systematic and random sampling techniques were employed. Purposive sampling was employed in delineating only areas which cut across the length and breadth of the abandoned road project within the study area. These areas included: Abiati, Oberekae, Etankpini and Mbat-Odukpani. Thereafter, the systematic (line transect) was employed to establish quadrat of 10 x 180 m, which had 18 quadrats of 10 x 10m.

After the 18 quadrats had been established along environmental gradient (abandoned road on both sides), simple random sampling technique was then applied to select 10 quadrats from which soil parameters were obtained. From each plot, soil sample were gotten at predetermined depths at 0–15 cm and 15–30cm of the soil, representing the top and the subsoil layers through a soil auger. The restriction of soil specimen to these depths was adopted because the layer provides the bulk of plant nutrients (Aweto, 2013) [2].

The soil samples were collected using soil auger and sterile containers respectively. Other instruments included; a ruler, a measurement tape, a sophisticated camera, and a handheld Garmin geographical positioning system (GPS) for obtaining sampling station coordinates. In each plot, soil samples were collected from four different points and bulked to represent a sample for each depth. However, 20 soil samples were gotten (10 soil samples at topsoil, 0-15cm and another 10 soil samples from the subsoil, 15-30cm). The soil samples collected were stored in receptor bags sealed, labeled air-dried and deposited at the University of Calabar Soil Science laboratory to be analyzed for soil physical, chemical and heavy metals properties using standard methods. In addition, 10 soil samples each (for topsoil and subsoil) were also obtained 200m away from the abandoned road (representing the secondary forest) which served as the control. In all, a total of sixty (20) soil samples were collected (within the abandoned road).

Laboratory analysis of soil samples

The obtained soil sample was air dried in seven (7) days. It was so carried out in other to stop every microbial occurrence within the soil. The air-dried soil was filtered with a 2 mm filter mesh to eradicate rubbles and stones. The output from the air-dried and sieved soil was for analysis to determine different parameters such as;

- "Particle size distribution was determined by the Bouyoueos (1951) [3] hydrometer method.
- Soil pH was determined in 1:1 (soil: water) ratio using the pH meter (Jackson, 1958).
- Organic carbon was determined using the Walkley and black wet oxidation method (Walkley and Black, 1974) [16].
- Total nitrogen was determined using the modified Kjeldahl digestion method (Jackson, 1958b).

- Available phosphorus was determined using the Bray No. 1-P method (Bray and Kurtz, 1945) [4].
- The exchangeable cations were leached with a IN NH40AC extraction method (Peech, 1965) [13].
- K and Na (Meq/100) were determined with a flame photometer.
- Ca and Mg were determined by the EDTA titration method.
- Exchangeable acidity was determined by the IN KCL-extraction method.
- Effective cation exchange capacity (ECEC) was by the addition of exchangeable bases to the exchangeable acidity.
- Percentage base saturation was by the use of the formula":

Results and discussion

Soil characteristics before and after road abandonment

Soil physico-chemical properties

The topsoil and subsoil soil properties are shown through Table1 and Figure 2. Result from Table1 showed that topsoil clay content had a mean value of 14 percent with a range of 5.0-29.0 percent, while subsoil clay content had a mean value of 13.3 percent with a range of 5.0-32.0 percent. Silt content at the topsoil had a mean value of 16.8 percent with a range of 10.0-32 percent, while subsoil mean value was 16.3 percent while a range was 8.0-30.0 percent. For sand, the topsoil content had a mean value of 69.2 percent with a range of 56.0-84.0 percent, while subsoil mean value was 70.4 percent within a range of 55.0-84.0 percent. This simply indicates that the soil in the study area is sandy-loamy in character.

Output from Table1 and Figure 2 also revealed that subsoil pH across the entire area had a mean value of 6.3 with a range of 4.96-6.89, while subsurface pH had a mean value of 6.31 and a range of 5.52-6.74. This therefore shows that the soils in the area are acidic soils. Organic carbon content (Org. C) had of the soil a mean value of 1.98 percent and a range of 0.50 to 4.32 percent at the surface soil level while, the mean value at the sub surface level was 2.25 percent within a range of 0.78-4.04. Similarly, topsoil total Nitrogen (TN) content had a mean of 0.23 percent and also ranged from 0.06-0.34 percent, while subsoil TN had a mean value of 0.29 percent with a range of 0.4-0.31 percent.

For phosphorus (P), the topsoil mean value was 0.23 mg/kg soils and subsoil mean value of 0.21 mg/kg. It also showed that topsoil calcium (Ca) content ranged from 45.6-74.31 cmol/kg, while the subsoil value had a mean value of 60 Cmol/kg range of 35.45-76.31 Cmol/kg. Magnesium (Mg) was observed to have a mean value of 269 mg/kg and range of 6.12-37.0 mg/kg at the topsoil level, while the subsoil had a mean value of 28.9 mg/kg with a range of 4.30-36.75 mg/kg. Also topsoil potassium had a mean value of 3.7cmol/kg with a range of 2.81-6.21 cmol/kg, while the subsoil had a mean value of 3.4 mg/kg with a range of 2.00-5.90 cmol/kg. In addition, sodium (Na) had a mean of 5.03cmol/kg with a range of 0.18-7.41 cmol/kg at the topsoil soil, while the subsoil had a value of 4.21cmol/kg with 0.5-6.62 cmol/kg as the range.

Nevertheless, Nitrogen (N) had mean of 0.73 mg/kg and a range of 0.01-2.52 mg/kg at topsoil, while the subsoil was having mean value amounting to 0.54 mg/kg and the range was 0.00-2.10 mg/kg. More so, topsoil aluminum (Al^{++++}) had a mean value of 0.86cmol/kg with a range of 0.0-3.01cmol/kg, while subsoil mean value was 0.4cmol/kg, with a range of 0.00-1.56cmol/kg. For Hydrogen (H+), the topsoil value ranged 0.68-2.3cmol/kg, while the subsoil had a mean value of 1.0 with a range of 0.57-2.03cmol/kg. Similarly, the effective cation exchange capacity (ECEC) had topsoil mean value of 4.53cmol/kg with a range of 3.68cmol/kg, while the subsoil mean value was 3.82cmol/kg with a range of 3.212-5.32cmol/kg. The base saturation (BS) of the entire soils at the topsoil had a mean value of 69.1 percent with a range of 46.0-87.0 percent, while at the subsoil; the mean value was 65.5 percent with a range of 45.0-74.0 percent.

Heavy metals contents

The heavy metals contents of soils within the study vicinity are captured in Table 2 It showed that iron (Fe) at the topsoil had mean value of 14.4 mg/kg with a range of 1.75-75.00 mg/kg, while the subsoil had a mean value of 14.01 mg/kg and a range 1.22-75.56 mg/kg. Cadmium (Cd) at the topsoil had a mean value of 1.58 mg/kg having range of 0.02-4.67 mg/kg, while subsoil mean value was 1.81 mg/kg within a range of 0.01-3.7 mg/kg. For Chromium (Cr), the topsoil mean value was 0.09 mg/kg with a range of 0.01-9.32 mg/kg, while subsoil the mean value 0.30 mg/kg with a range of 0.0-2.10 mg/kg. Similarly, topsoil lead (Pb) had mean of 0.08 mg/kg with a range of 0.01-0.572 mg/kg, while at the subsoil; the mean value was 0.05 mg/kg with a range of 0.01-0.203 mg/kg.

Also, copper (Cu) had a mean value of 1.072 mg/kg with a range of 0.01-0.572 mg/kg at the topsoil; while the subsoil had a mean value was 0.8mg/kg and a range of 0.01-3.01mg/kg. For Nickel (Ni), topsoil mean value was 1.39mg/kg and a range of 0.01-3.2mg/kg, while the subsoil mean value was 1.39 mg/kg and range of 0.02 – 221 mg/kg. For vanadium (Vn), the topsoil mean value was 0.22 mg/kg with a range of 0.01-2.04 mg/kg, while the mean value at the subsoil was 1.22 mg/kg and range of 0.01.08 mg/kg. Lastly, Zinc (Zn) had a mean value of 3.90mg/kg and a range of 0.75-7.27 mg/kg at the topsoil, while the subsoil had a mean value of 3.8mg/kg with a range of 0.13-6.39 mg/kg.

Table 1: Physico-chemical properties of soil along the adjoining 20 km abandoned road

s/n	Description	pH	Org.C %	T.N %	P (Mg/kg)	Ca Cmol	Mg (Mg/kg)	K Cmol kg	Na (Mg/kg)	N (Mg/kg)	cmol/kg A1***	cmol/kg H^+	cmol/kg ECEC	B %	Clay %	Silt %	Sand %
1	0-15 CMS 1	6.54	2.54	0.11	0.7	61.0	31.1	3.04	7.41	0.03	0.41	2.3	5.64	69.0	5.0	14.0	81.0
2	15-30	5.52	1.43	0.9	0.6	55.43	29.21	4.17	6.62	0.02	0.18	1.06	4.50	73.0	8.0	13.0	79.0
3	0-15 CMS 2	6.01	1.96	0.18	0.8	57.8	27.35	4.22	5.45	0.05	0.01	0.57	3.68	82.0	12.0	23.0	65.00
4	15-30	6.24	266	0.4	0.8	65.65	34.27	3.09	5.50	0.06	0.00	0.57	3.40	68.0	5.0	11.0	84.0
5	0-15CMS 3	6.13	4.32	0.32	0.24	47.43	27.58	3.15	6.81	0.01	2.1	2.03	6.01	56.0	13.0	16.0	71.0
6	15-30	6.11	3.76	0.29	0.25	76.31	34.33	2.00	4.60	0.02	1.56	1.21	5.32	73.0	8.0	30.0	62.0
7	0-15CMS 4	4.96	2.43	0.31	0.42	74.31	28.71	4.10	6.51	0.06	3.01	1.00	4.20	80.0	10.0	32.0	58.0

8	15-30	5.84	1.06	0.23	0.37	75.42	36.75	3.01	5.82	<0.001	0.01	0.84	3.37	45.0	11.0	18.0	71.0
9	0-15CMS 5	6.85	2.36	0.30	<0.02	47.00	6.12	6.21	0.18	2.00	0.0	2.14	5.25	46.0	6.0	10.0	84.0
10	15-30	6.44	3.25	0.31	<0.01	35.45	4.30	5.90	0.5	<0.001	0.42	2.03	4.43	70.0	20.0	8.0	72.0
11	0-15CMS 6	6.5	0.50	0.06	<0.02	57.42	29.10	2.81	3.00	2.52	0.58	0.70	3.98	69.0	23.0	11.0	66.0
12	15-30	6.6	1.57	0.08	<0.01	63.05	32.04	2.70	2.0	1.59	0.0	0.91	3.21	63.0	5.0	25.0	70.0
13	0-15CMS 7	6.89	0.99	0.29	<0.01	59.00	30.1	3.14	6.31	0.55	0.48	1.03	3.75	75.0	21.0	23.0	56.0
14	15-30	6.74	4.04	0.13	<0.01	53.00	35.0	4.02	5.50	0.24	0.32	1.01	3.56	72.0	32.0	13.0	55.0
15	0-15CMS 8	6.46	2.31	0.21	<0.03	61.15	37.0	3.38	6.71	0.56	0.53	0.68	4.43	51.0	14.0	12.0	74.0
16	15-30	6.32	3.03	0.18	<0.02	63.06	29.08	2.59	4.80	2.10	0.2	1.05	3.61	54.0	24.0	13.0	63.0
17	0-15CMS 9	6.17	1.15	0.34	<0.02	67.66	32.03	4.21	3.42	0.77	0.88	0.96	3.78	87.0	29.0	14.0	57.0
18	15-30	6.72	0.78	0.27	<0.01	71.56	36.25	3.08	2.97	0.64	0.74	0.85	3.43	74.0	9.0	18.0	73.0
19	0-15CMS 10	6.41	1.19	0.18	<0.01	45.6	19.5	3.19	4.45	0.74	0.61	1.13	4.56	76.0	7.0	13.0	80.0
20	15-30	6.56	0.88	0.10	<0.01	41.2	17.4	3.11	3.81	0.69	0.56	1.12	3.32	63.0	11.0	14.0	75.0

Key
Org. C = Organic Carbon, T.N = Total Nitrogen, P = Phosphate, N = Nitrogen, ECEC = Effective cation exchange capacity, BS = Base saturated

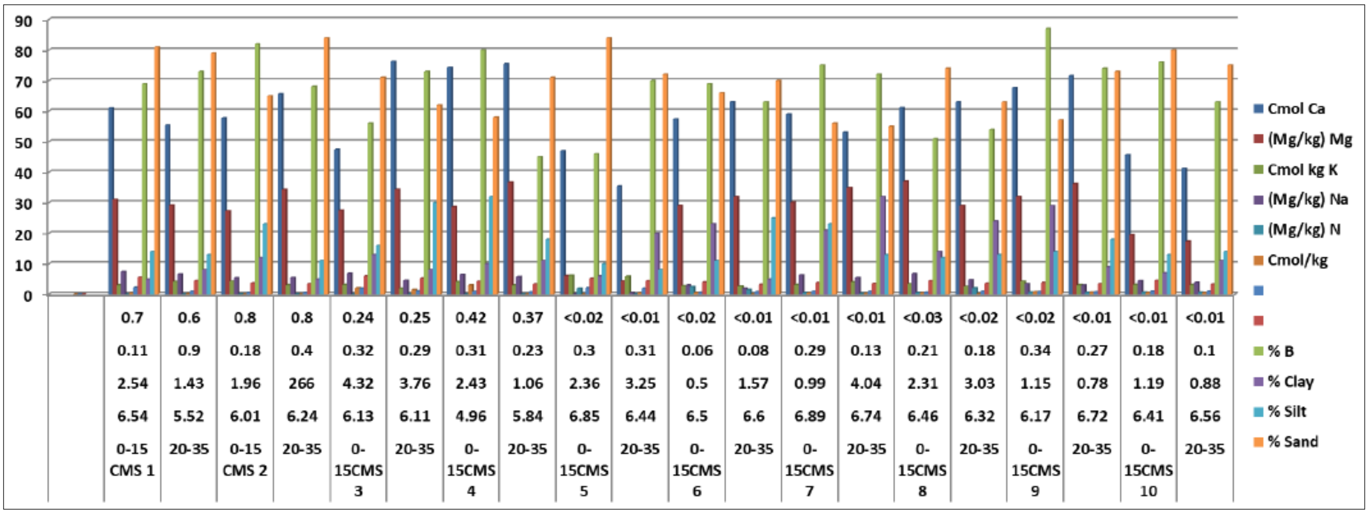

Fig 2: Physico-chemical properties of soil sample

Table 2: Heavy Metal Mg/Kg analysis of soil samples

S/N	Sample ID Surface/subsurface soil	Iron (Fe)	Cadmium (Cd)	Chromium (Cr)	Lead (Pb)	Copper (Cu)	Nickel (Ni)	Vanadium (Va)	Zinc (Zn)
1	S	2.56	0.41	0.08	0.02	0.43	2.30	<0.02	3.16
2	SS	1.22	0.56	0.05	0.03	0.59	1.18	<0.01	1.14
3	S	3.52	<0.02	0.09	0.01	0.44	1.01	<0.02	4.01
4	SS	2.46	<0.01	0.02	0.03	0.68	2.16	<0.02	3.13
5	S	1.75	0.53	0.01	0.02	0.56	1.13	<0.01	1.19
6	SS	2.76	0.41	0.01	0.02	0.32	2.16	<0.02	2.15
7	S	3.64	0.23	0.03	0.01	0.65	0.21	<0.01	7.27
8	SS	1.91	0.52	0.56	0.03	0.567	0.22	<0.02	5.48
9	S	75.00	2.54	0.32	0.02	<0.02	0.39	2.04	6.01
10	SS	73.56	3.74	0.07	0.02	<0.01	0.48	1.08	5.02
11	S	12.72	1.76	0.03	0.573	2.25	2.43	<0.02	6.16
12	SS	13.63	3.10	2.10	0.223	0.31	1.12	<0.01	6.39
13	S	11.52	2.28	0.16	0.06	0.85	<0.02	<0.02	4.54
14	SS	10.41	3.54	0.08	0.02	2.02	<0.01	<0.01	5.05
15	S	9.95	1.71	0.11	0.01	0.48	3.01	<0.01	2.92
16	SS	11.74	1.68	0.05	0.08	1.47	1.86	<0.02	0.13
17	S	13.15	4.67	0.05	<0.02	2.01	2.02	<0.02	0.75
18	SS	12.89	2.06	0.06	<0.01	0.45	1.50	<0.01	5.80
19	S	9.90	1.62	0.03	0.04	3.03	1.48	<0.01	3.87
20	SS	9.50	2.44	0.04	0.02	1.20	3.21	<0.02	3.34

***Source*:** Author's-fieldwork-analysis-2022

Tables 3: Soil physico-chemical properties

S/N		Topsoil		Subsoil	
	Soil properties	Mean	Range	Mean	Range
1	pH	6.3	4.96-6.89	6.31	5.52-6.44
2	% organic carbon	1.98	0.50-4.32	2.25	0.78-4.04
3	Total Nitrogen (%)	0.23	0.06-0.34	0.29	0.4-0.31
4	Phosphorus (g/Kg)	0.23	0.01-0.042	0.21	0.01-0.37
5	Calcium (mol)	57.84	45.6-74.31	60.0	35.45-76.31
6	Magnesium (g/Kg)	26.9	5.12-37.0	28.9	4.30-36.75
7	K (mol/Kg)	3.75	2.81-6.21	3.4	2.00-5.90
8	Sodium (g/Kg)	5.03	0.18-7.41	4.212	0.5-6.62
9	N (g/Kg)	0.73	0.01-2.52	0.54	0.001-2.10
10	$A1^{+++}$ (mol/kg)	0.86	0.0-3.01	0.4	0.00-1.56
11	H^+ (mol/kg)	1.30	0.68-2.3	1.0	0.57-2.03
12	ECEC (mol/kg)	4.53	3.68-6.01	3.82	3.21-5.32
13	BS %	69.1	46.0-87.0	65.5	45.0-74-0
14	Clay 14.0	14.0	5.0-29.0	13.3	5.0-32.0
15	Silt	16.8	10.0-32.0	16.3	8.0-30.0
16	Sand	69.2	56.0-84.0	70.4	35.0-84.0

Source: Author's fieldwork analysis 2022

Table 4: Soil heavy metals analysis

S/N	Topsoil		Heavy metal analysis		Subsoil	
	soil properties	**Mean**	**Range**	**Mean**	**Range**	**Limit WHO 1996**
1	Iron (Fe)	14.4	175-75.00	14.01	1.22 - 73.56	50.00
2	Cadmium (Cd)	1.58	0.02-4.67	1.81	0.01 - 3.74	0.02
3	Chromium (Cr)	0.09	0.01-0.32	0.30	0.01 - 2.10	1.30
4	Lead (Pb)	0.08	0.01-0.0572	0.05	0.01 - 0.203	2
5	Copper (Cu)	1.072	0.02-3.03	0.8	0.01 - 2.02	10
6	Nickel (Ni)	1.4	0.01-3.01	1.39	0.01 - 2.21	10
7	Vanadium (Vn)	0.22	0.01-2.04	1.22	0.01 - 1.08	1.1
8	Zinc (Zn)	3.99	0.75-7.27	3.8	0.13 - 6.39	0.60

Source: Author's fieldwork analysis 2022

Test of the hypothesis

Ho: This part of the analysis gives answer to the study hypothesis which is stated as follows:

There are no significant dimensions in the degraded forest soil properties adjoining the 20km Lafarge Africa Plc Road abandonment.

H_I: There are significant dimensions in degraded forest soil properties adjoining 20km Lafarge Africa Plc Road abandonment.

This hypothesis was tested using Principal Components Analysis (PCA). PCA process through varimax rotation and the Kaiser rule of selecting specially elements having Eigenvalues >1(Gaur and Gaur, 2006) produced eight (8) extracted components (Table 4.5). The derived components amounted to 92.4% of the overall change within the original soil data (Table 5). From result, four components having positive and negative values loaded heavily in PC_1. The positive loadings indicated increase in soil properties following the road abandonment, while the negative implied decrease in soil properties following the road abandonment. The soil components were surface ECEC (0.927), surface clay (-0.839), surface sand (0.821) and surface H^+ (0.818). PC_1 is said to measure surface ECEC and it was 17.6 % of overall changes in linear combination of soil properties. PC_2 possessed three soil properties of positive and negative values which loaded strongly in it; the variables were subsurface potassium (-0.940), subsurface magnesium (0.912) and subsurface calcium (0.882). The component indicates subsoil exchangeable bases which amounted to16.2% variance in the soil properties.

PC_3 also had three soil properties having significant values which loaded heavily in it; the variables were surface potassium (-0.896), surface magnesium (0.862) and surface sodium (0.859). PC_3 exemplified surface swapping bases which amounted to 10.9% variance in the soil data set. On PC_4, three soil properties having positive with negative values loaded heavily in it; the variables were subsurface total nitrogen (0.873), subsurface pH (-0.853) and subsurface potassium (0.850). This component stood for subsoil nitrogen, amounting to 10.8% variance in the soil properties. PC_5 explained 10.5 % of the variance in the data set. PC_5 represented surface Aluminium and the variable was Al^{++} (0.868). On PC_6, two soil variables loaded on it; the variables were subsoil clay (0.823) and subsoil sand (-0.807). PC_6 influenced 10.1 % of the variance in original data set, represented subsoil clay/sand. PC_7 had a single soil variable that loaded on which signified subsoil base saturation (0.892). PC_8 also had only one soil variable that loaded positively; the variable was surface phosphorus (0.821). This component triggered 7.0 % of the variance in the soil data and exemplified surface phosphorus.

The result in Table 5 shows that topsoil ECEC, subsoil exchangeable bases, topsoil exchangeable bases, subsoil nitrogen, surface Aluminium, subsoil clay/sand, subsoil base saturation and topsoil phosphorus are the dimensions in soil properties and also represent soil properties that progressively changed after the abandonment of Lafarge Africa Plc. The absence of disturbance associated with road construction activities and the regrowth of vegetation over time have considerable impact on soil nutrients. For instance, as depicted or shown in PC_1, there was an increase in topsoil ECEC after the abandonment. The rapid restoration of vegetation helps in soil erosion control which also affects the concentration of soil nutrients. The increase in debris and fine particulate matter help to increase the ECEC. High ECEC value after road abandonment is attributed to an increase on litter accumulation that causes increased organic matter in the soil. The output assonates with the discovery of Hassan, Murabbi and Victor (2016) that organic matter remained a reservoir for soil exchangeable cations, influencing increase in ECEC in the soil. The increase in soil properties is synomynous with increase in the amount of biomass injected into the soil with a favourable soil moisture and temperature period that enhanced the level of litter decomposition (Lal, 2005).

Another likely reason for the increase in soil properties is the reduced frequency of disturbance following the road abandonment. Nevertheless, the level of "exchangeable bases varied considerably. The high concentration of exchangeable calcium (which increases with nutrient intake or litter breakdown in soils) could be attributed to high undergrowth which did not disrupt the organic matter cycle to environmental condition – surface run-off of nutrient. The levels of exchangeable bases fluctuated due to varying vegetation characteristics. The level of cation exchange capacity (CEC) and other soil properties show positive increase due to the increases in cover, tree size and the number of legumes" (Aweto, 1981; Offiong and Iwara, 2011) [2]. Sand content in the area is high which a characteristic of the study location is. In addition, the re-establishment of vegetation following road abandonment is shown to favour the build-up of nutrient as is seen in the positive increase in base saturation. Base saturation increased under higher vegetal cover. In a related study, Snelder (2001) [15] indicated base saturation with higher in soil under tree canopies rather than those in open grassland. The result in Table 5 therefore shows that topsoil ECEC, subsoil exchangeable bases, topsoil exchangeable bases, subsoil Nitrogen, topsoil aluminium, subsoil clay/sand, subsoil base saturation and topsoil phosphorus are seriously impacted upon by road construction activities.

Table 5: Principal Component Analysis results of soil components after road abandonment

Variables	Principal components							
	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7	PC_8
ECEC (S)	.927	.108	.039	.120	-.039	.017	.192	-.193
Clay (S)	-.839	.114	.219	-.136	.002	.059	.148	-.382
Sand (S)	.821	.001	-.272	.047	-.432	-.086	-.111	-.047
H+ (S)	.818	-.065	-.108	.156	-.099	-.065	.388	.048
OC (S)	.777	.162	.014	.144	.376	.119	.281	.181
BS (S)	-.631	-.011	.330	-.043	.235	-.471	.030	.370
K (SS)	-.140	-.940	-.022	.144	-.043	.080	.071	-.058
Mg (SS)	-.143	.912	.173	.219	.078	.041	-.038	.050
Ca (SS)	-.014	.882	-.009	.255	.228	.003	-.001	-.193
H+ (SS)	.246	-.795	-.211	-.128	.020	.230	.234	-.333
Silt (SS)	.350	.781	-.032	-.216	.061	-.085	.220	-.299
K (S)	.179	-.121	-.896	.028	.070	.071	.182	.134
Mg (S)	-.349	.162	.862	.037	.148	-.042	-.125	.075
Na (S)	.094	-.001	.859	.085	.296	.062	-.013	.361
TN (SS)	.202	-.194	.104	.873	-.068	-.140	.276	.000
pH (SS)	-.316	-.144	-.015	-.853	-.206	.063	.210	.153
P (SS)	.035	.258	-.044	.850	.047	-.199	-.010	.295
Na (SS)	-.043	.556	.126	.608	.094	.199	-.201	.291
Al++ (S)	.066	.270	.207	.058	.868	.027	-.084	-.227
pH (S)	.080	-.305	-.013	-.101	-.778	.336	.256	-.267
Silt (S)	-.316	-.137	.175	.086	.685	.066	.001	.527
TN (S)	-.049	-.149	-.352	-.097	.569	.420	.519	-.001
Ca (S)	-.437	.084	.400	.153	.480	-.155	-.227	.142
Clay (SS)	-.239	-.443	.074	-.112	-.007	.823	-.103	.024
Sand (SS)	-.088	-.294	-.048	.335	-.054	-.807	-.106	.269
OC (SS)	.188	-.089	-.142	.055	-.106	.779	.410	.004
BS (SS)	.116	-.175	-.058	-.018	-.306	.043	.892	.111
Al++ (SS)	.310	.243	-.364	-.117	.105	.219	.666	-.209
ECEC (SS)	.498	-.062	-.248	.326	.049	.316	.585	-.303
P (S)	.271	.065	.246	.236	.098	-.448	-.002	.821
Total	5.27	4.87	3.28	3.23	3.15	3.04	2.79	2.11
% of Variance	17.58	16.23	10.92	10.76	10.48	10.12	9.29	7.04
Cumulative %	17.58	33.81	44.73	55.49	65.97	76.1	85.38	92.42

*Variables underlined with loadings ±≥0.80 are considered significant
Source: Author's fieldwork analysis 2021

Conclusion and recommendations

The findings of the study clearly show that the 20 km Lafarge Africa cement evacuation road abandonment has had some impacts on the biophysical elements along the Akamkpa – Odukpani segment of Cross River State. The study found that the road construction and subsequent abandonment negatively impacted on the soil nutrients. It showed that in spite of the road abandonment, no substantial increase was observed in the build-up of nutrients. This is because the contents of organic carbon, total nitrogen, phosporus, calcium, pottasium, sodium, aluminium, hydrogen and base saturation remained comparatively higher in the secondary forest soils over the degraded forest soils adjoining the 20 km Lafarge Africa Road.

It also shows that the amounts of organic carbon with total nitrogen significantly differed between the two studied soil communities with higher values recorded within the secondary forest. In spite of the obvious differences in soil nutrient, the study reveals that the Lafarge Africa road abandonment favours the build-up of essential nutrients within the soil. It was expected as the contents of topsoil ECEC, subsoil exchangeable bases, topsoil exchangeable bases, subsoil nitrogen, topsoil aluminium, subsoil clay/sand, subsoil base saturation and topsoil phosphorus progressively increased after the abandonment of the Lafarge Africa Plc road project.

The positive contributions to nutrient restoration in the soil are attributed to the establishment of vegetation after abandonment which gives the soil protection against harsh environmental conditions such as rainfall. The rapid establishment of vegetation reduces the loss of soil nutrients to runoff and adds nutrients in the soil via litter dropping and decay. Furthermore, the study revealed that the road construction activities in the area did not result in heavy metal pollution. This is because of the low pollution load index observed in the degraded forest soil adjoining 20 km Lafarge Africa Road. Therefore, it was recommended that the vvegetation around Lafarge Africa Plc abandoned road should be protected and maintained. Any form of illegal logging activities and deforestation should be discouraged. If this is done, it will help to keep the soil compact and reduce soil erosion and soil loss. This will have considerable impact on soil nutrients by increasing the rate of nutrient buildup.

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Appendices

Plate 1: Soil sample collection

Plate 2: Soil topographic features along the newly tarred lafarge road in the study