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RESEARCH ARTICLE

SAND MINING AND ENVIRONMENTAL SUSTAINABILITY: A SPATIAL PATTERN ANALYSIS OF SELECTED LOCATIONS IN RIVERS STATE

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ABSTRACT

Sand is a valuable resource for construction and other purposes. However, illegal, and unscientific sand mining portends ecological disasters on a large scale. It often results in serious environmental problems such as land degradation, loss of agricultural lands and biodiversity as well as pollution resulting to various diseases. The study assessed the non-compliance of the mining industry with the provisions of the law as prescribed in the Mineral and Mining Act 2007 with respect to restricted areas for mining and reclamation works after extraction of mineral deposits. It further highlights the non-compliance of remediation or reclamation activities of the mining industries, and the inefficient implementation and enforcement of the reclamation works in parts of Rivers State, Nigeria as provided for in Sections 90(2) and 115 of the Mining Act 2007. The Geographic location and attributes of sites were captured for spatial analysis using Geographic Information System (GIS) and associated Remote Sensing techniques. The results show that the Rumuolemini location has a largest surface area of 18.26 Hectares with a perimeter of 2.47km, and Isiodu 2 has the smallest surface area of 0.41Hectares with a perimeter of 0.02km. The highest volume of 21979.274m³, and 4708.985m² surface area was recorded in post dredge site 4. Also, the volume of 563.512m³ with a surface area of 334.360m². These locations are substantially linear and impact on the New Calabar River. Some of the site study revealed that the site is currently used as a dumpsite for various wastes despite the intense urban and industrial development proximal to residential buildings. Furthermore, that sand mining should be strictly monitored and a stiffer penalty for non-compliance with the reclamation activities after mining.

KEYWORDS

Land Degradation, Sand mining, Pollution, Non-Compliance, GIS, Remote Sensing)

1. INTRODUCTION

Sand mining is a mineral exploitation activity that is propelled by the increase demand for sand and gravel for construction and sustenance of the environment. The mining activities has both negative and positive impact on the ecology of our environment and in particular the geometry of the bordering water bodies. The Federal Republic of Nigeria, judging from its rather unpalatable experience from the exploration, exploitation and refining of petroleum products especially in the Niger Delta Area has resolved to give environmental issues in project implementation a priority concern. Legislations like Government Harmful Waste Disposal Decree No. 42 of 1988 and the National Policy on the Environment with the Federal Environmental Protection Agency (FEPA) backed by Decree No. 58 of 1988, to enforce environmental protection regulations, had been put in place Ishighwor (Hart and Eze, 2024).

The environmental impact of dredging revolves mainly around land and marine disposal of dredged materials undermines the expectation of the Sustainable Development Goals No 6 and 15, (<https://sdgs.un.org> Accessed on 31st August 2024). The immediate impacts of land disposal of dredge spoils include, changes in the topography of the site and the composition of the surface layer of the disposal ground. Air pollution and odour which may be harmful to humans, pollution of the water table, the destruction of fauna and flora and impaired visual quality. The effects of disposing dredged material in open waters may be temporary or permanent. Permanent impacts include; Changes in the bottom morphology and alterations in the nature of the materials constituting the

upper layer of the bottom surface. Destruction and disturbance of flora and fauna, Ishighwor, (Hart and Eze, 2024). Similarly, the temporary impacts include; turbidity, degradation of water quality at the disposal site and pollution and discoloration of beaches and other recreational areas. The imposition of restrictions on disposal of dredge materials in open waters is due to the impact of such disposal on the marine environment. In particular, are contaminated or polluted materials, which have led to placement of such materials in designated containment facilities or not permitting dredging at all. Pollution occurs when the concentrations of various chemical or biological constituents exceed a level at which a negative impact on amenities, the ecosystem, resources and human health can occur (Muhammad et al., 2011). Thus, it is very important in the planning of sand mining (dredging) projects to carefully characterize and describe the nature of material to be dredged, not just in an overall sense but location by location and at sediments which are truly contaminated that require special handling and those which are a little different from natural sediments in the region and could therefore be disposed at open water sites. Significant financial savings can be obtained by not having to contain or handle in a special fashion all of the dredged materials. A special purpose map prepared by a surveyor can give a bird's eye view of such data as an essential tool in pre-dredge project planning and eventual implementation. The main thrust of this work is to appraise and analyse the spatial pattern of selected locations of Rivers State impacted with sand mining.

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Plate 1: A Specimen Sand Mining Site at the Study Area. Source: Author field data, 2024.

2. STUDY AREA DESCRIPTION

The sand mining and dredging sites under study cuts across several locations in four Local Government Areas of Rivers State which comprises of Eleme, Emohua, Etche and Obio/Akpor. As shown in figure 1, Eleme is bounded in the north by Oyibo, south by Okrika, East by Ogu/Bolo and west by Obio/Akpor and spatially located between projected coordinates of 530655.19m.N, 291361.17m.E to 528164.11m.N, 292207.41m.E. Emohua is bounded by Abia and Imo States to the north, Obio/Akpor and Oyigbo to the south, Omuma to the east and Ikwerre to the west, and spatially located between projected coordinates of 540118.07m.N, 262841.97m.E, to 559153.08m.N, 248257.47m.E. Etche is bounded by Abia and Imo States to the north, Obio/Akpor and Oyigbo to the south, Omuma to the east and Ikwerre to the west, and spatially located between projected coordinates of 546617.44m.N, 287820.07m.E to 568049.33m.N, 293708.10m.E, whereas Obio/Akpor Local Government Area is bounded by Etche, Port Harcourt City, Oyibo/Elemena and Emohua to the North, South, East and West Respectively and spatially located between projected coordinates of 540675.13m.N, 267539.51m.E to 536380.02m.N, 287939.67m.E (Eze et al., 2023; Amachree et al., 2019).

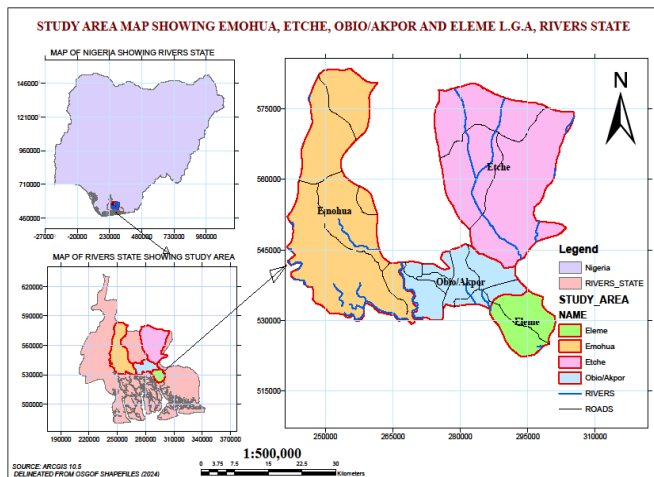


Figure 1: Study Area Map. Source: Delineated from OSGOF Shapefiles of Nigeria.

3. MATERIALS AND METHODS

Instrument Selections: Instruments used in course of this research work are; Garmin 78csx GPS receiver, 100m steel tape, Personal Protective Equipment (PPE), field book, calculator and car for transportation.

Table 1: Software and hardware selection		
S/N	Software	Hardware
1	Arc-GIS 10.1	Dell Latitude E6540 Laptop
2	Microsoft Word 10	Redmi Note 12 Android Phone with 50 mape pixel camera
3	Microsoft Excel 2013	Casio 991 fx calculator
4	Google Earth Satellite imagery	
5	UTM Geo Map 2023	Garmin 78csx GNSS Receiver
6	Open Street Map 2024	Accessories
7	Surfer 10.0	Application

3.1 Data Acquisition

3.1.1 Secondary Data Source

Table 2: Secondary Data Sources			
S/N	Open Source Data	Significance	Data Types
1	Google Earth	Charting of Coordinates	Imagery, raster
2	Google Labels	Ground features identification/names	Vector
3	OpenStreetMap	Highly detailed GIS data with different levels of accuracy and completeness	Vector data such as buildings, roads, vegetation and waterways

3.2 Data Sources

Field Reconnaissance Survey: Field reconnaissance was carried out to obtain a first-hand information of selected sand mining sites under study. Photographs were also taken cum attribute information of communities in the study area as shown in plate 1.

Principle of GPS Positioning: Coordinates were generated based on the principles of GPS positioning. The precise travel time of the signal is necessary to determine the distance, or so-called range, to the satellite. Since the satellite is in an orbit approximately 20,200 km above the Earth, the travel time of the signal will be roughly 0.07 sec after the receiver generates the same signal. Time (t) delay between the two signals is multiplied by the signal velocity (speed of light in a vacuum) c, to determine the range to the satellite; $r = c \times t$

Where (r) is the range to the satellite, (t) is the elapsed time for the wave to travel from the satellite to the receiver and (c) is the range to the satellite (Fubara, et al., 2014).

Two fundamental methods are employed in determining distances to satellite, this includes code ranging and carrier phase-shift measurements, from distance observations made to multiple satellites, receiver positions are computed from distance observations made to multiple satellite (El-Rabbanny, 2002).

Ground Truth Field Observations: (Garmin 78csx) GPS receiver was used to obtain the point coordinates of selected sand mining sites under study, camera was also used to take photographs of mining sites scene in the study areas. The spatial and attribute information of the various solid sand mining sites were also obtained.

Charting of Coordinate Points: The coordinates observed in the field were charted on Google earth imagery to ascertain if the position of the various mining sites (is within the study areas and this was achieved by launching Google earth imagery and importing the shapefile of Eleme, Emohua, Etche and Obio/Akpor Local Government Areas of Rivers State.

On Screen Vectorization: is the method of tracing geographic features from another dataset (usually an aerial, satellite image, or scanned image of a map) directly on the computer screen. In this research work, after importing the shape file of the Local Government Areas of which sand mining sites are located to Arc-GIS 10.1 environment as a layer, an open source data known as Open Street Map (OSM) was used to show the roads leading to the various mining sites and other necessary features needed for the map where some vector operations were also performed. The distances and directions between points defining each sand mining sites were measured, this was necessary to determine the extent (Surface perimeter and Area) covered by each site as shown in figures 2 and 3.

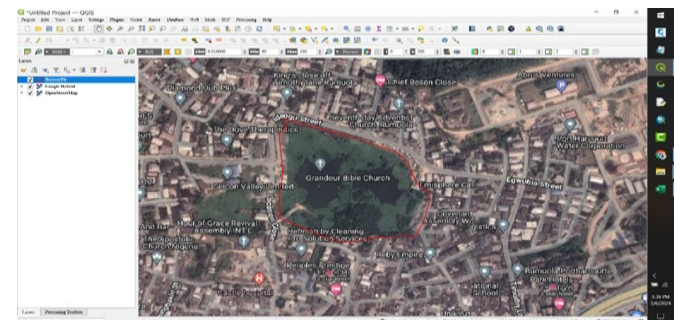


Figure 2: Screen Print of Sand Mining Site Delineation at Ogbogoro axis of the study area

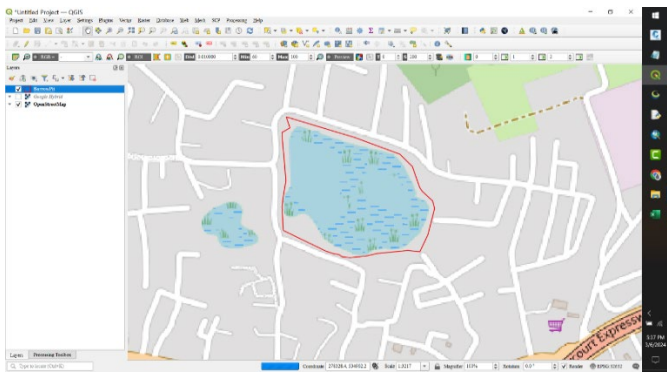


Figure 3: Screen Short of Digitized Mining site in Arc-GIS Software Environment

3.3 Volumetric Analysis

Direct measurement is rarely made in volumetric analysis since it is difficult to actually apply a unit of measure to the material involved, instead, indirect measurements are obtained by measuring lines and areas that have relationship to the volume desired as shown in plate 2 (Hart, 2024). The principal systems used to measure volume are the cross-section method, the unit area and/or the contour-area method (Ezeigbo, 2022). We adopted the cross-sectional area of volumetric computational techniques as expressed in equations 1-4 (Ezeigbo, 2022; Hart, 2024)

$$V = \frac{A_1 + A_2 + A_3 + \dots + A_{n-1} + A_n}{n} \times L \tag{1}$$

$$V = D \times \frac{A_1 + A_2}{2} \tag{2}$$

$$\in v = \frac{D_1(A_1 + A_2)}{2} + \frac{D_2(A_2 + A_3)}{2} + \frac{D_3(A_3 + A_4)}{2} + \dots \tag{3}$$

$$\in v = D \frac{A_1 + A_2}{2} + A_2 + A_3 + \dots + A_{n-1} \tag{4}$$

Where A₁, A₂, A_n are the cross-sectional Areas; L- Distance between the Areas; V- the Volume. The cross-sectional areas are averaged and multiplied by the distance between then to obtain the volume required. The quantity of materials removed from the different sand mining sites in the study area underscore the impact on the environment negatively in terms of the water bodies and the general ecology of the area.

4. RESULTS

The results obtained comprises of spatial, attribute information of mining sites in study areas and a sample of volumetric data analysis. Spatial

pattern analysis were also carried out to examine the distribution pattern of mining sites under study. Figures 4 and 5 shows sand mining sites along Rumuolumeni, Ogbogoro, Rumuopkarali, Rumualogu and Isiodu Emohua sections of the new Calabar River.



Figure 4: Sand Mining Sites delineated along Rumuolumeni, Ogbogoro, Rumuopkarali, Rumualogu and Isiodu Emohua sections of the new Calabar River.



Figure 5: On-screen Vectorization of Sand Dredging Site at Ogbogoro Town, Obio/Akpor L.G.A, Rivers State.

Table 3: Geospatial Data of Some Sand Mining Sites in Obio/Akpor L.G.A

S/N	Locations	L.G.A	Eastings (m.E)	Northings (m.N)	Area (m ²)	Perimeter (m)
1	48 Zilly Drive Rumueme	Obio/Akpor	275011	533322	25,530.92	873.21
2	Choba, Along East West road,	Obio/Akpor	269193	540820	6,690.99	269.19
3	Egbelu ozodo	Obio/Akpor	271948	535410	1,270.20	117.34
4	Eleme	Eleme	285833	536740	5,818.85	213.99
5	Eneka Along Igwuruta road by eneka Junctions	Obio/Akpor	282883	541318	3,765.64	178.09
5	Eneka by World Bank Assemblies	Obio/Akpor	283011	540864	23,467.38	803.98
6	Obiri Ikwerre	Obio/Akpor	273077	539444	22,417.48	819.46
7	Ogbogoro market Road	Obio/Akpor	270314	534940	37,065.72	909.21
8	Opm Road Iwofe Rumuolumini	Obio/Akpor	273755	533336	6,261.12	209.51
9	Rukpoku	Obio/Akpor	278356	540864	12,281.94	321.08
10	Rumuigbo along East West Raod	Obio/Akpor	275746	538516	6,307.35	226.10
11	Rumukalagbor	Obio/Akpor	279583	532836	489.81	97.61
12	Rumuola	Obio/Akpor	278355	534833	59,558.07	1,376.55

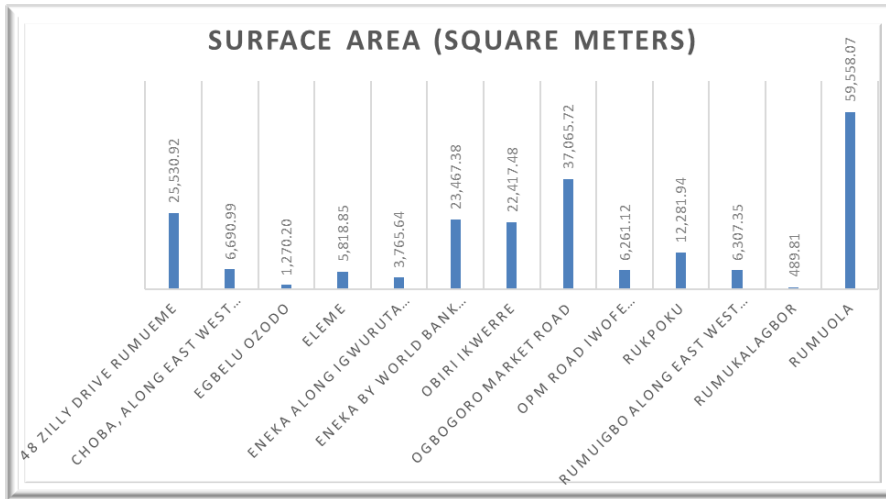


Figure 6: Surface Area Distribution of Sand Mining sites (Red Mud) under study

Table 4: Specimen Geospatial Data of Some Sand Mining Sites in the Study Area

S/N	Locations	L.G.A	Eastings (mE)	Northings (mN)	Area (Hectares)	Perimeter (m)
1	Isiodu 1	Emohua	266573	539657	4.99	1,276.11
2	Isiodu II	Emohua	266493	539809	0.41	242.15
3	Isiodu	Emohua	266301	540009	4.29	1298.1
4	Rumualogu I	Obio/Akpor	267431	539087	5.89	1353.32
5	Rumualogu II	Obio/Akpor	267501	538899	1.29	452.05
6	Rumuokparali I	Obio/Akpor	283011	540864	4.18	966.58
7	Rumuokparali II	Obio/Akpor	273077	539444	11.21	2009.29
8	Rumuolumeni	Obio/Akpor	271196	530796	18.26	2407
9	Rumuwoke Ogbogoro	Obio/Akpor	269725	536051	3.91	876.07
10	Anaka Ogbogoro	Obio/Akpor	270109	535413	9.94	1308.03
11	Akpajo Eleme	Eleme	287553	532736	1.35	651.49
12	Chokocho I	Etche	284225	552435	5.51	1934.56
13	Chokocho II	Etche	284716	552315	0.59	381.96
14	Chokocho III	Etche	284716	551882	0.83	528.65
15	Chokocho IV	Etche	285464	552604	10.22	2381.35

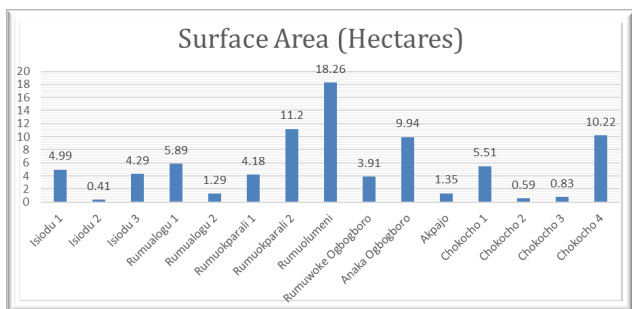


Figure 7: Surface Area Distribution of Sand Dredging sites at LGA's under study

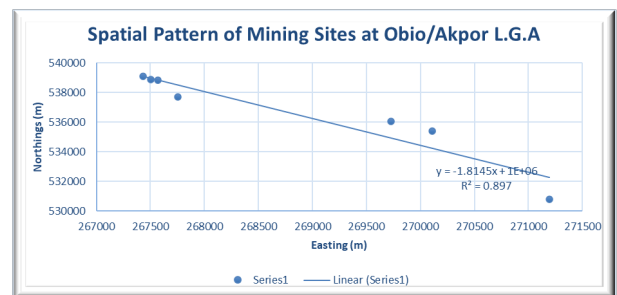


Figure 9: Linear Distribution of Sand Dredging sites at Rumuolumeni, Ogbogoro, Rumuokparali, and Rumualogu Sections in Obio/Akpor L.G.A, Rivers State

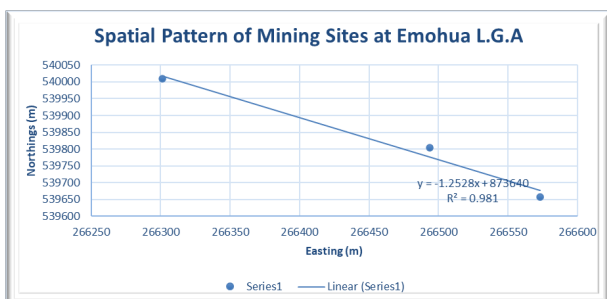


Figure 8: Linear Distribution of Sand Dredging sites at Isiodu, Emohua L.G.A

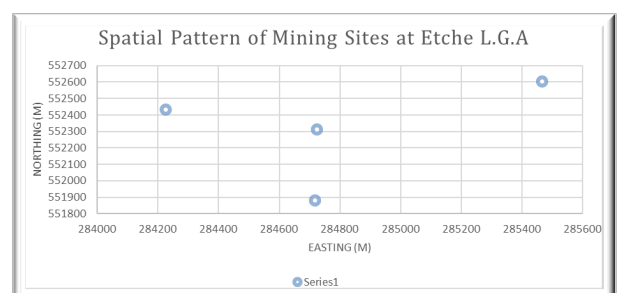


Figure 10: Random Distribution of Sand Dredging sites at Etche L.G.A, Rivers State

4.1 Grid volume Computations for Dredging Site 1

4.1.1 Upper Surface

Grid Size: 68 rows x 100 columns

X Minimum: 279931.964

X Maximum: 280014.530

X Spacing: 0.834

Y Minimum: 529894.996

Y Maximum: 529950.793

Y Spacing: 0.837

Z Minimum: 2.590

Z Maximum: 12.898

Lower Surface

Level Surface defined by Z = 2.86

Volumes

Z Scale Factor: 1

Total Volumes computed by each method:

Trapezoidal Rule: 12843.186m³

Simpson's Rule: 12841.782m³

Simpson's 3/8 Rule: 12843.897m³

Cut and Fill Volumes

Positive Volume [Cut]: 12845.684m³

Negative Volume [Fill]: 2.497

Net Volume [Cut-Fill]: 12843.186m³

Areas

Planar Areas

Positive Planar Area [Cut]: 2811.893

Negative Planar Area [Fill]: 23.948

Blanked Planar Area: 1771.098

Total Planar Area: 4606.940m²

Surface Areas

Positive Surface Area [Cut]: 3151.444m²

Negative Surface Area [Fill]: 24.196m²

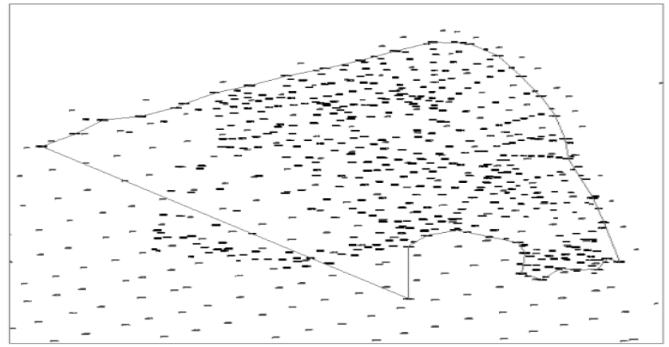


Figure 11: Pre and Post of Sand Stockpile for Dredging Site 1

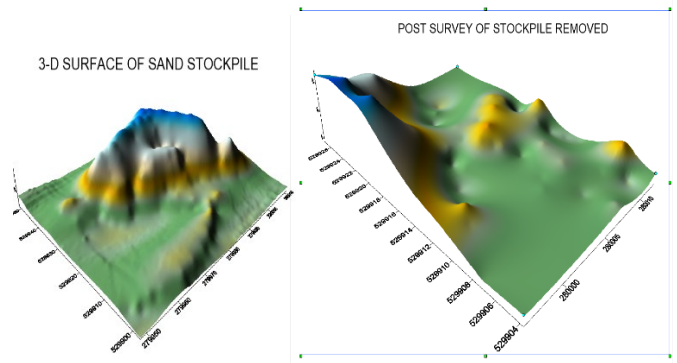


Figure 12: 3-D Surface of Sand Stockpile and Post Survey of Stockpile removed for Dredging site in the Study Area

3D-SURFACE OF SAND STOCKPILE

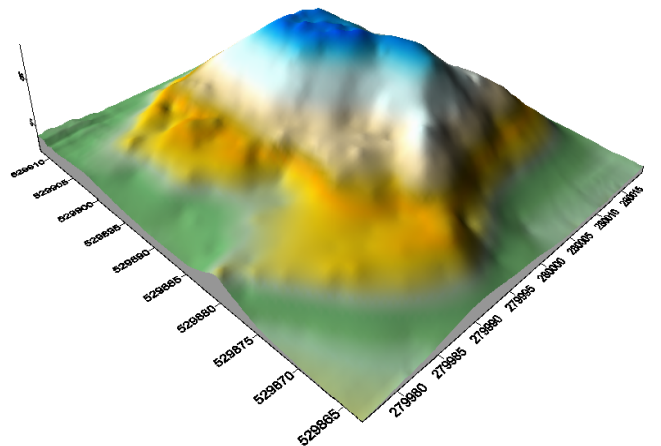


Figure 13: 3-D Surface of Sand Stockpile for dredging site 4

4.2 Summary of Report of Specimen Volumetric Analysis of Sand Stockpile at one of the Sites in the Study Area

- Volume of Post Dredge Survey 1: 7,736.365 Cubic Metres
Surface Area of Post Dredge Survey 1: 2,824.164 Square Metres
- Volume of Post Dredge Survey 2: 563.512 Cubic Metres
Surface Area of Post Dredge Survey 2: 334.360 Square Metres
- Volume of Post Dredge Survey 3: 5819.349 Cubic Metres
Surface Area of Post Dredge Survey: 3557.467 Square Metres
- Volume of Post Dredge Survey 4: 21979.274 Cubic Metres
- Surface Area of Post Dredge Survey: 4708.985 Square Metres

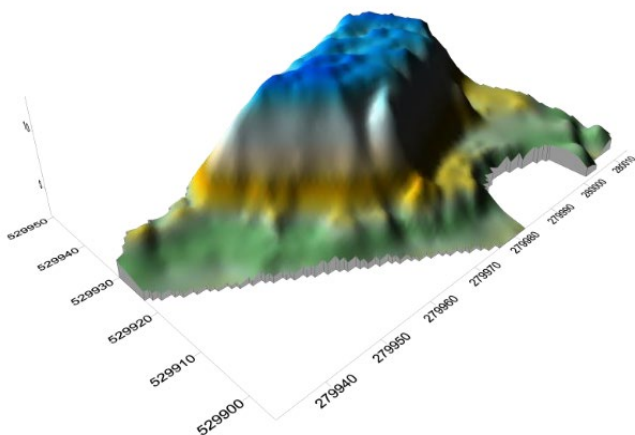


Figure 10: 3-D Surface of the Sand Dump for Dredging Site 1, at Study Area

5. DISCUSSIONS

Findings from the study revealed that the sand mining activities in selected sites under study is seriously impacting on the environment, especially at sections of the new Calabar River in Obio/Akpor and Emouha Local Government Areas of Rivers State. A total surface perimeter and Area of 6,414.07 meters and 21.10 Hectares of land respectively were recorded for sand mining sites use for excavation of red mud for construction works, the research also recorded a total surface perimeter and area of 16,791.27 meters and 82.87 Hectares of land respectively, use for dredging and mining of shape sand. The sand are used for construction of engineering works within the Local Government Areas under Study and Rivers State at large. The study also revealed that Rumuolemini location has the largest surface area of 18.26 Hectares with a perimeter of 2.47km, and Isiodu II has the smallest surface area of 0.41Hectares with a perimeter of 0.02km as contained in tables 3 and 4. The study also noted the spatial pattern of selected mining sites with locations in Obio/Akpor and Emouha Local Government Areas substantially linear and impact on the New Calabar River, whereas Etche Locations were randomly distributed. This is shown in figures 6-9 respectively. Some of the site study revealed that the site is currently used as a dumpsite for various wastes despite the intense urban and industrial development proximal to residential buildings. Plate 2 shows an abandoned sand mining site whose land use is not supporting any economic venture or environmental sustainability. The specimen volumetric analysis shows the relative quantity of materials removed from the sub-surfaces of the various sites in the study area. The highest volume of 21979.274 Cubic Metres was recorded post dredge of site 4 with a surface area of 4708.985 Square Metres. Conversely, post dredge of site 2 recorded the lowest volume of 563.512 Cubic Metres with a surface area of 334.360 Square Metres. The information on the volume analysis bring to the fore the issue of the economic consideration as against the environmental import of the various sand mining activities dotting the study area.



Plate 2: Abandoned Sand Mining site at Ogbogoro axis of the study area, impacting on the environment. Source: Author field data, 2024.

6. CONCLUSION

The purpose of the study was achieved using geospatial techniques. The integration of ground truth field observations, remote sensing and GIS approaches yielded to the results and findings of the study. Ground truth observations was very useful in determining the extent of land mass being used for various sand mining sites under study in a remote environment without having physical contact to the scene. In the same vein, the determination of the specimen volumetric analysis reveals the quantity of materials removed without remedial action to preserve the environment in line with Sustainable Development Goals (SDG) No 6 and 15. This study will be veritable to the Ministry of Environment to monitor sand mining activities in the study area.

RECOMMENDATIONS

Regulations of sand mining activities in the study areas is imperative to forestall imminent environmental consequences and ecological instability such as river bank and shoreline collapse, uncertainties in sea bed topography, indiscriminate reclamation and conversion of wetlands to mining sites, amongst others. A recovery programme be put in place to mitigate the devastating effect of post sand mining activities in the study. An advocacy on the long-term environmental effect on the increasing sand mining activities as against the prevailing economic benefits of the moment.

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