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# Geospatial Assessment of the Impacts of Sand Mining Activities in Benin City, Edo State Nigeria

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## Authors' contributions

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

This study assessed the geospatial impacts of sand mining activities in Benin City, Edo State, Nigeria. There are thirty five (35) burrow pits in Benin and eleven (11) were used for the study. Similarly, three (3) distinct datasets and sources were used to determine the spatial extent of environmental degradation as a result of sand mining activities in Benin City. The first data set was the 19th January, 2019 satellite imagery of each of the mining sites. This high resolution remotely sensed data was used in the determination of areal extent of the sand mining sites. The second set of data was the Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) 30meters resolution digital elevation model (DEM). The ASTER-DEM was used as an input dataset in the determination of the volume of sand that have been mined in each site and compilation of three – dimensional model (3D Model) of each the sand mining site. The third set of data was the geographic coordinates of the mining sites. They were sourced from field survey with the use of global positioning system (GPS).The study concluded that sand mining and development cannot be entirely separated but mining should be done in a sustainable manner with less of environmental degradation. It is recommended that miners should be regularly sensitized by the government on environmental degradation and about the fragile nature of the environment. The government

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regulatory body should ensure that Environmental Impact Assessment (EIA) is carried before mining pits are approved for mining activities. Also illegal burrow pits should be short down to check environmental degradation.

*Keywords: Sand mining; environmental degradation; Global Positioning System (GPS); Geographic Information System (GIS).*

## 1. INTRODUCTION

Soils are dynamic and diverse natural systems that lie at the interface between earth, air, water, and life. They are critical ecosystem service providers for the sustenance of humanity [1]. Pit sand (laterite), river sand and gravel are constituents of soil which take ages to be formed but are mined in a matter of days [2].

The focus of this paper is on laterite, this is a soil layer that is brownish and rich in iron and aluminum. It is mostly found in tropical and subtropical regions where climate is humid. Laterite soils may contain clay materials. According to Mwangi [3], soil has many uses, it is needed for agriculture, as a habitat and in construction, but the financial benefits from mining has made companies to be involved, they mine both legally and illegally with little or no concern for the environment.

Mining activities which involve the abstraction of the earth is the world's oldest and important occupation only second to agriculture. In essence, the earlier period of mining is the history of civilization [4]. Soil mining has both positive and negative environmental impacts. Mining of sand both on small and large-scale occur in major parts of Nigeria. With an estimated 16 million housing deficit and infrastructural development in the country, there will continue to be great request for sand and other construction materials in developing areas [5].

Mining process, undeniably has brought affluence and employment prospect in mining areas, but concurrently has led to widespread environmental degradation and erosion of traditional values in the society. Furthermore, the indiscriminate and unscientific mining, absence of before mining (Environmental Impact Assessment 'EIA') and after mining action and management of mined areas are making the delicate ecosystem more susceptible to environmental degradation [6]. Though, sand mining is likely to be controlled by law in many places and Benin City in particular [7], opined

that it is still many a times done unlawfully. It is quickly becoming an ecological problem as the request for sand rises in industry and construction [7].

The consequence of human action such as sand mining on land include disruption of the landscape, distorted topography, agriculturally barren land, and creation of pools of water for breeding pests, deforestation and general degrading of the ecosystem [5]. Similarly, the careful deforestation of an area for sand mining may cause the extinction of some plants and exodus of some animals/bird species that feed on such plants or depend on them for shelter [8-12]. However, Benin City and its environs have been most extensively extracted in terms of sand. As a result of this, in many parts of the area there have been alteration of the original luxurious evergreen landscape into sand mine plunders.

Studies related to the floristic composition of the mining areas have been conducted by several researchers in different parts of the world [13-17]. Until recently, most studies on mining were concerned with the impact on ground water and the environment [5,18,19]. It is obvious that the aforementioned researches did not assess the geospatial impacts of sand mining activities. To this end, an assessment of geospatial impacts of sand mining activities in Benin City, Edo State, Nigeria is necessary.

### 1.1 Study Area

Benin City, the study area, is located in the mid-western part of southern Nigeria. It was the political headquarters of Mid-Western Region, later Bendel state and now Edo State. Benin City is located in the South-South Geopolitical zone of Nigeria and it covers the developed portion of five local government areas namely; Oredo, Ikpoba Okha, Egor, Ovia North-East, and Ughwode Local Government Areas of Edo State. As other traditional cities in Nigeria, the city is surrounded by a city wall and moat which has in recent times been transformed into a drainage channel. The moat is a semi-concentric

network of earth work spanning between 2000 miles-500 miles [20].

Benin City geographically lies approximately within latitudes 6° 26' and 6° 31' N; and longitude 5° 35' E and 5° 41' E [21] see Fig. 1. Benin City is surrounded in the west by the rural parts of Ovia North-East and Egor Local Government Area; in the north by the rural parts of Uhumwode local Government Area; in the east by Ikpoba -Okha Local Government Area; and in the south by the rural parts of Oredo and Ikpoba- Okha Local Government Areas. However, with the advent of development, these aforementioned Local Governments Areas have joined up to making the Benin City of today. The City now covers a total area of about 112sq.km [21].

Benin City lies on the sedimentary layer of the south sedimentary basin of the Benin foundation which is characterised by top reddish-brown sandy laterite alluvia soil. The lowlands are parts or the vast coastal plain which form the southern fringe of Nigeria, and are generally below 150 meters in height. The area is drained by series of incised rivers and small streams flowing in the north direction. The city is indeed well drained by two main rivers. They are the Ikpoba River which drains the north eastern part of the city and the Ogba River drains the south western part of the city [22].

The geological structure of Benin City generally consist of two major foundations; these are the crystalline rock of the Precambrian basement complex and sedimentary rock of the cretaceous tertiary and quaternary formation of Miocene-Pleistocene age often referred to as the Benin formation [23]. There is large quantity of clay minerals in the lateric soil of Benin City region which holds little air, this retain lots of water which form a persistent adhesive mass. This is because filtration of water is reduced to the simplest lowest by particles [24].

Benin City is characterized by tropical climate with rainfall almost throughout the year. The heaviest rainfall is usually within the months of June through September. The dry season occurs within the months of November through March. The mean annual rainfall is usually above 2000 mm and the relative humidity is about 70% with a mean monthly temperature of 27 C and an annual range of 3% [25]. Similarly, rainfall, temperature, wind and relative humidity are the most substantial climatic elements in Benin City. Two principle air masses prevail in the City,

these are the tropical maritime and tropical continental [26]. These climatic elements have stimulated the growth of tropical rainforest which is fairly evergreen in nature.

## **2. METHODOLOGY**

Three (3) distinct datasets and sources were used to determine the spatial extent of environmental degradation as a result of sand mining in Benin-City. The first dataset was the 19<sup>th</sup> January, 2019 satellite imagery of each of the sampled mining sites. They were downloaded from Google Earth Desktop Application. This high resolution remotely sensed data was used in the determination of areal extent of the sand mining sites. The second set of data was the Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) 30 meters resolution digital elevation model (DEM). This grid dataset was sourced from the National Atmospheric and Aero-Space Administration (NASA) website.

The ASTER-DEM was used as an input dataset in the determination of the volume of sand that have been mined in each site and compilation of three – dimensional model (3D Model) of the sand mining site. The third set of data was the geographic coordinates of the mining sites. They were sourced from field survey with the use of global positioning system (GPS). The coordinates the mining site were taken and were later fed into the Arc GIS software for precise identification of each of the mining sites in the satellite imagery and ASTER-DEM. This exercise is referred to as ground trothing.

Furthermore, there were 35 locations of sand mining sites (burrow pits) in the study area [27]. All the sites were visited with the view to collecting their GPS reading as well as the lowest and highest elevation in the site. Unfortunately and because of the volatility as well as the suspicious attitude of most the operators, access was granted to eleven (11) sites for spatial measurement representing about 31.4% of the registered pits. Thus, based on Cooper and Schindler [28] as cited in Fab-Ukozor and Ejem [29] who reported that 5% of the population is ideal for a sample size and anything that exceeds 5% may be useful for good statistical inference, the number was used in determining the spatial extent of environmental degradation as a result of sand mining in Benin-City.

In addition, basic data capture procedures which included importation of the satellite imagery of the mining sites into Arc GIS 10.1 software where it was geo-referenced, polygon layer created to represent area and on-screen digitization carried out. Other operations carried out include clipping of ASTER-DEM to demarcate the mining sites, reprojection from the World Geodetic System (WGS) lat-lon geographic coordinate system (GCS) to WGS-Universal Transverse Mercator (UTM) projection, Zone 32 North.

Similarly, the coordinates of various locations of mining sites were captured using Global Positioning System (GPS) device at the mean resolution of 3 meters, and were also imported into the Arc GIS 10.1 environment for *ground truthing*. This simply means matching the ground points with that of satellite imageries and ASTER DEM. This was followed by the utilization of *zonal statistical algorithm* in Arc GIS 10.1 to compute the *zonal statistics* of all the sampled sand mining sites. It was the output of the zonal statistics which include the minimum, maximum and mean elevation, depth and areas which were used as input in the computation of the actual volume of and that have been excavated from each zone (site).

Arc GIS 10.1 automatically computes the volume of sand excavated at each mining site as a product of area covered by each zone (mining site) and the difference between the maximum and minimum pixels elevation. It is the difference between the maximum and minimum pixel elevation that is referred to as the “*depth*” of the mining pit. Similarly, 3D Models of all the sampled mining sites were also compiled using the 30 meters resolution ASTER DEM for easy visualization of the extent of degradation of the environment by sand mining activities.

Initial procedure adopted in 3D mapping include generation of 5000 random points (RP) at an average distance of 5meters apart using create random tool, for use in elevation values extraction from the ASTER DEM of the mining sites. The rationale for generating up to 5000 RP was to facilitate a smooth surface. In other words, the higher the number of RP created, the smoother the surface. This was followed by elevation extraction using extraction extension and computation of x, y coordinates of all the generated elevation values using calculate field geometry tool. The elevation database of all the sample mining sites created were exported to Surfer 11 Software where they were converted to grid and 3D surface analyses carried using gridding and 3D surface mapping tools.

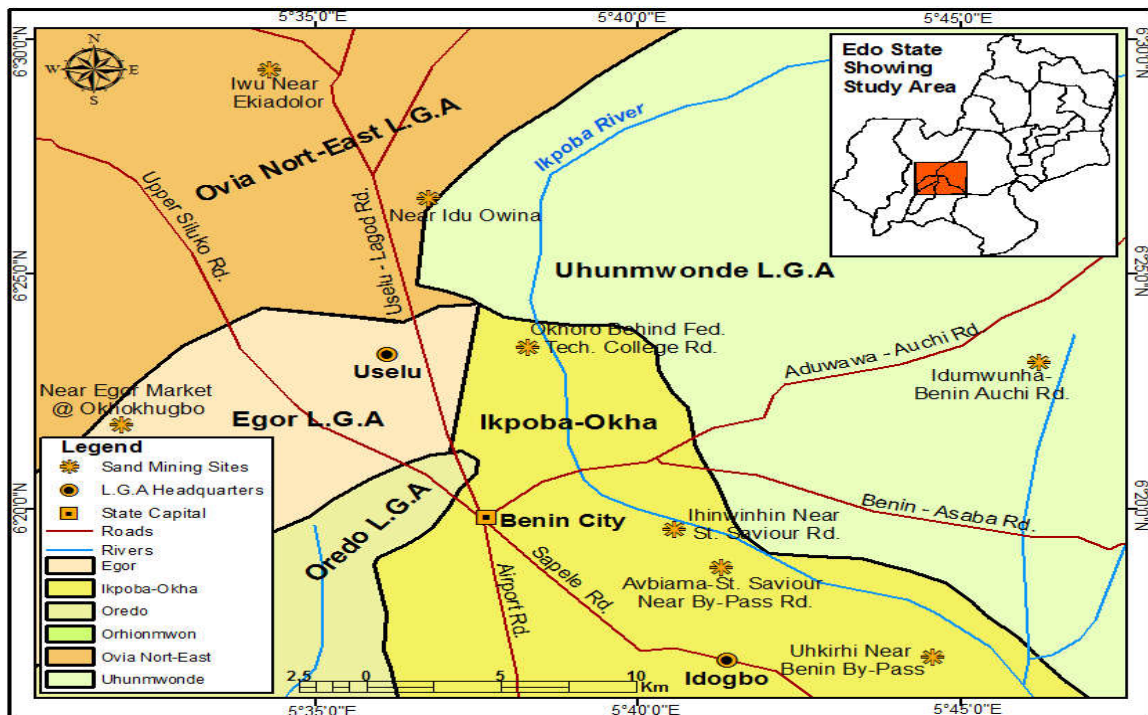


Fig. 1. Showing sand mining sites in the study area (Source: Edo State Ministry of Land and Survey)[27]



### **3. RESULTS AND DISCUSSION OF FINDINGS**

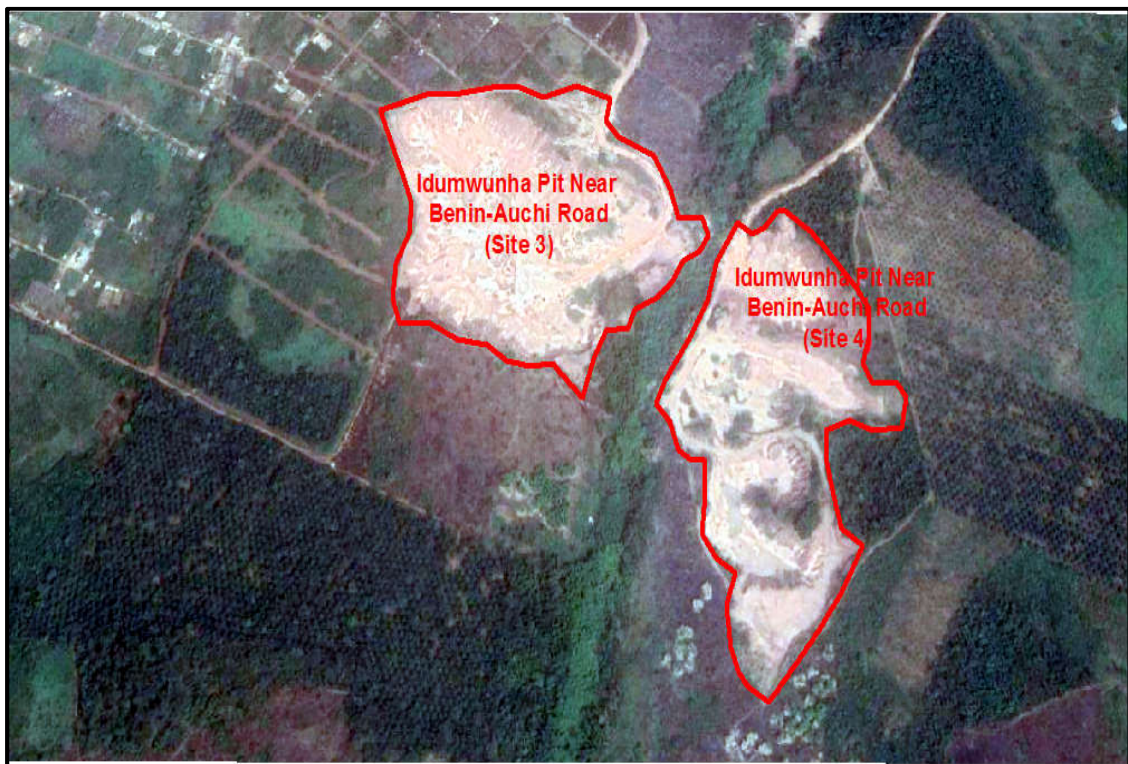
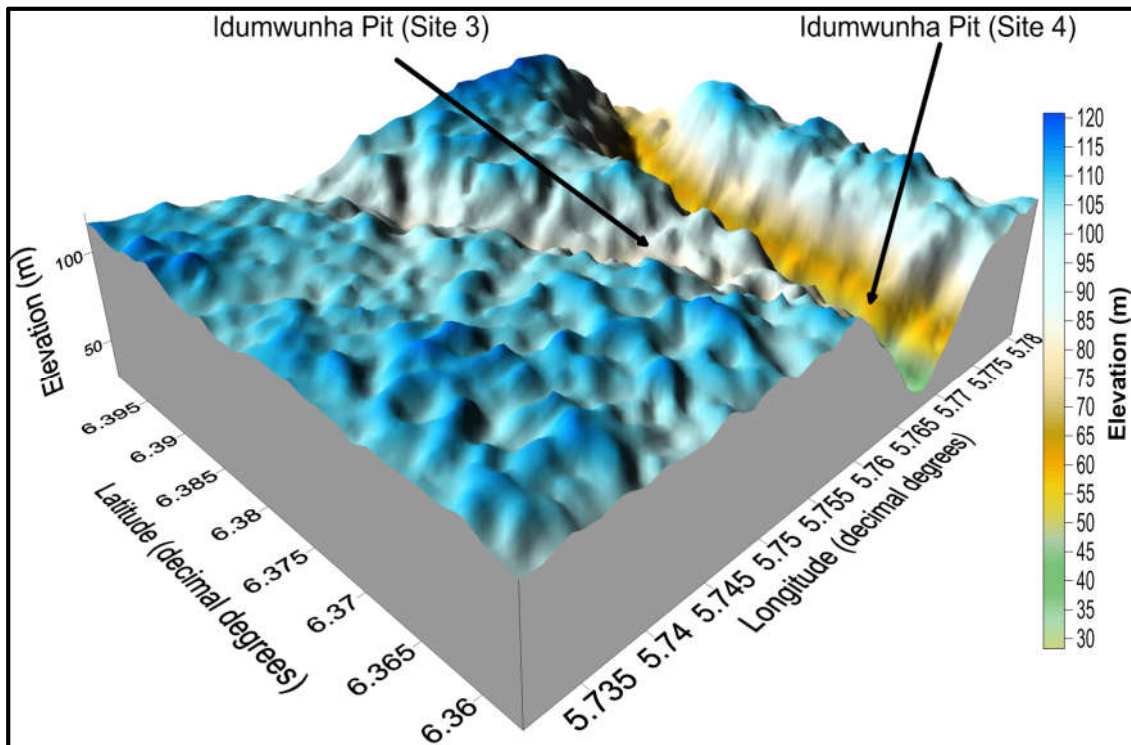
The result section is organised into plates, satellite and 3D imagies of the degraded envionment of the study area.



**Plate 1. Activities of sand miners showing the extent of land degradation in Ikhueniro burrow pit**

*Source: Photographed by Authors, 2019*

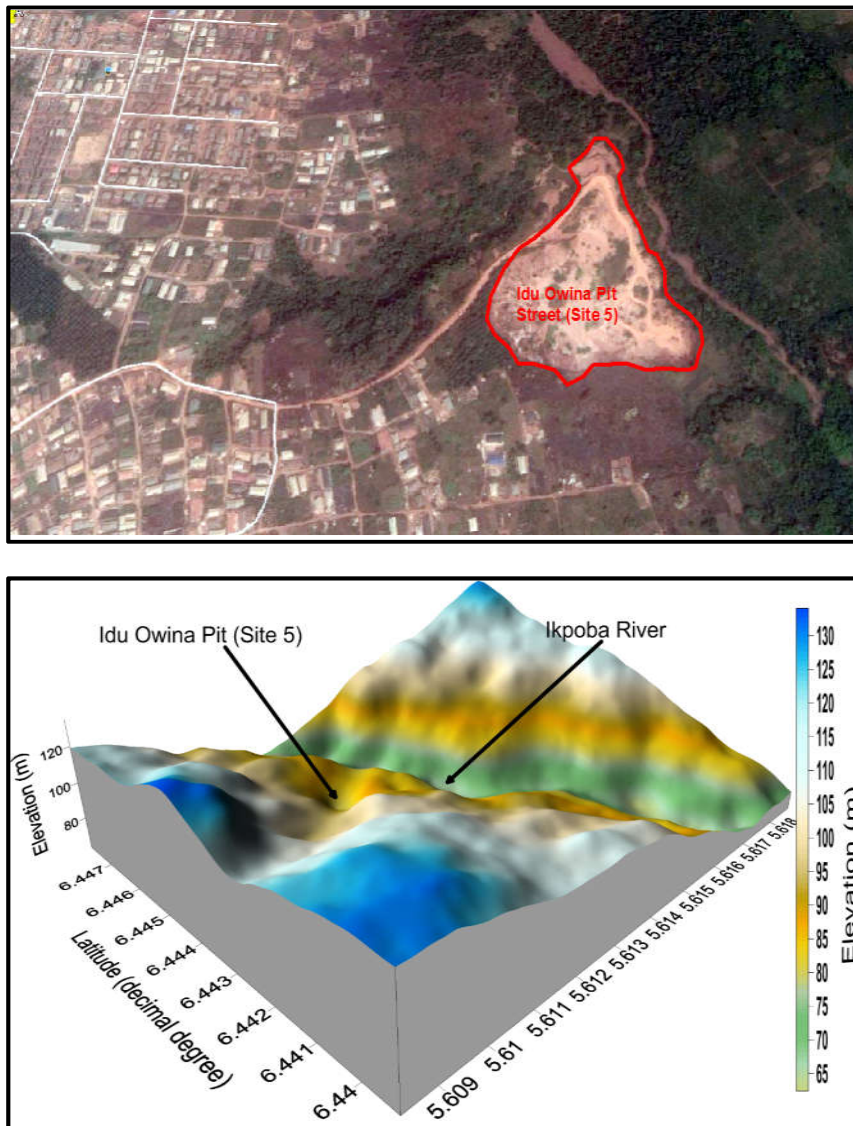
### Satellite and 3D Images of Some Burrow Pits and the Extent of Land Degradation



a) Satellite Imagery; b) 3 D Image

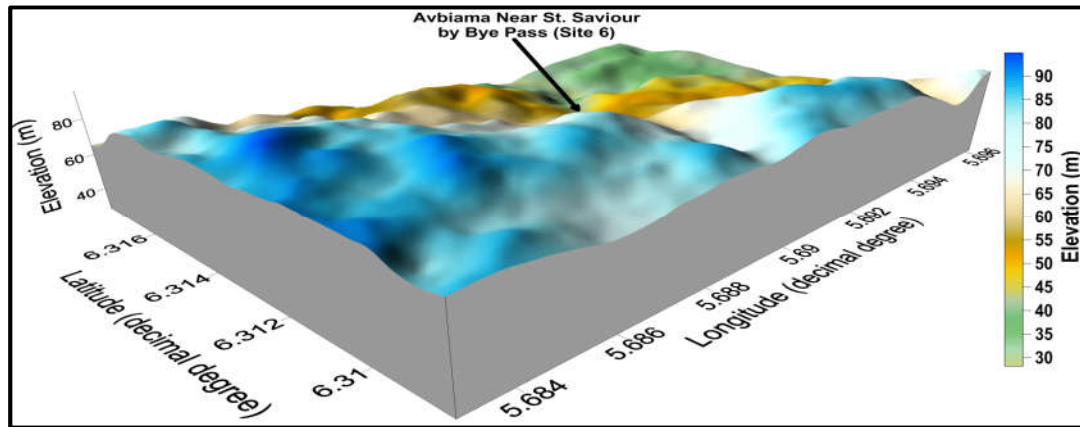
**Fig. 2. Spatial extent of environment degradation by Sand Mining in Idumwunha Pit**  
(Source: Google Earth, 2019; Fieldwork, 2019)





**Fig. 3. Spatial extent of environment degradation by Sand Mining in Idu Owina Pit**  
(Source: Google Earth, 2019; Fieldwork, 2019)

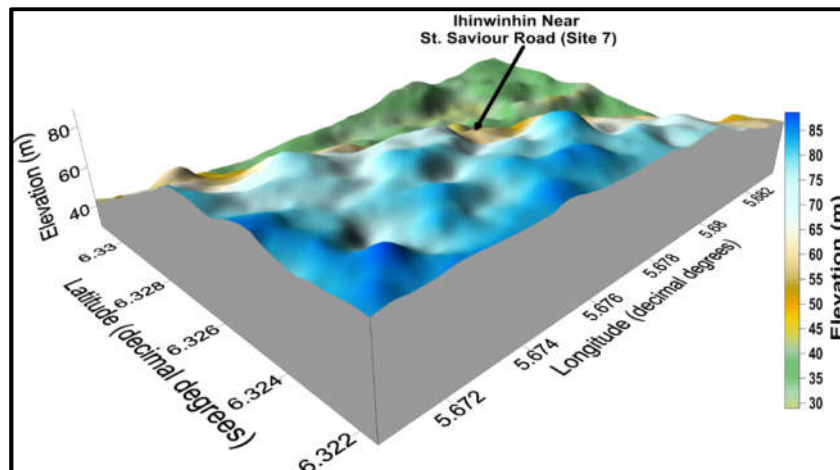




a) Satellite Imagery; b) 3D Image

**Fig. 4. Spatial extent of environment degradation by Sand Mining in Avbiama Pit, Near St. Saviour by Bye Pass**

(Source: Google Earth, 2019; Fieldwork, 2019)



**Fig. 5. Spatial extent of environment degradation by Sand Mining in Ihinwinhin Pit, Near St. Saviour Road**

(Source: Google Earth, 2019; Fieldwork, 2019)



**Table 1. GIS/Spatial measurement of burrow pits**

Site No	Description	Coordinates		Elevation (m)				Area (m <sup>2</sup> )	Depth (m)	Volume (m <sup>3</sup> )
		Longitude	Latitude	Min	Max	Mean	STD			
1	Iwu Pit (Ovbiogie 1)	5.574806	6.488609	83	120	102.95	9.31	141914.0	37	5,250,818
2	Iwu Pit (Ovbiogie) II	5.571005	6.489565	89	126	105.45	8.16	124654.0	37	4,612,198
3	Idumwunha I Near Benin Auchi Road	5.751158	6.381515	79	116	97.92	8.11	1163120.0	37	43,035,440
4	Idumwunha II Near Benin Auchi Road	5.761834	6.374311	72	114	91.16	8.74	1136270.0	42	47,723,340
5	Near Idu Owina Street	5.613294	6.443731	64	105	83.39	10.79	96846.5	41	3,970,707
6	Avbiana Near St Saviour by Bye-Pass Rd1	5.689080	6.313003	48	85	65.57	9.03	158215.0	37	5,853,955
7	Ihimwinhin Near St Saviour Road	5.676802	6.326543	32	84	58.65	12.55	276156.0	52	14,3 60,112
8	Uhkirhi Near Benin Bye-Pass	5.739415	6.284074	34	78	54.10	12.44	237801.0	44	10,463,244
9	Uhkirhi Near Benin Bye-Pass	5.743485	6.279967	35	74	57.17	10.10	226295.0	39	8,825,505
10	Okhoro Behind Fed. Tech. College Road	5.638539	6.388764	35	80	50.85	11.66	210953.0	45	9,492,885
11	Near Egor Market @ Okhokhugbo	5.533620	6.362764	48	66	57.92	4.56	35478.4	18	638,611
						75.01		3807702.9		14020620

Source: Field study, 2019

From Table 1, the elevation of the burrow pit at Iwu pit 1 is 120 m above sea, covering an area of 141,910 m<sup>2</sup> and the volume of sand that had been excavated was 5,250,818 M<sup>3</sup>. On the other hand at Iwu pit II, the elevation is 126 m with an area of 124,654 m<sup>2</sup> and 4,612,198 m<sup>3</sup> as the volume of sand that had been excavated. In Idumwunha pit 1 along Auchi Road, the elevation is 116 m covering an area of 1,163,120 m<sup>2</sup> and 43,035,440 m<sup>3</sup> volume of sand had been excavated from the area. Similarly, in Idumwunha pit II, there was an elevation of 114 m above sea level, covering an area of 1,133,627 m<sup>2</sup> and the volume of sand that had been excavated stood at 47,723,340 m<sup>3</sup>. Also the pit at Idu-Owika, had an elevation of 105 m covering an area of 96,846.5 m<sup>2</sup> and the volume of sand that had been excavated was 3,970,707 m<sup>3</sup> as the volume of sand that had been excavated. At Ihimwinhin pit, the elevation was 84 m above sea level with an area of 276,156 m<sup>2</sup> and 14,360,112 m<sup>3</sup> as the volume of sand that had excavated.

Furthermore, at Ukhirhi pit, the elevation was 74 m above sea level, covering an area of 226,295 m<sup>2</sup> and 8,825,505 as the volume of sand that had been excavated. At Okhoro pit, the elevation was 80 m above sea level covering an area of 210,953 m<sup>2</sup> and 9,492,885 m<sup>3</sup> of sand had been excavated. Lastly, at Okhokhugbo pit the elevation was 66m covering an area of 35,478.4 m<sup>2</sup> and 638,611 m<sup>3</sup> as the volume of sand that had been excavated.

Fig. 2, satellite imagery and 3D image of Idumwunha pit along Benin – Auchi road, the spatial extent of environmental degradation is massive as the two pits are almost merging into one. This will to a large extent make the land and the area unproductive for other land uses.

Fig. 3, satellite imagery and 3D image of Idu-Owina Pit. The sand mining site is close to residential area, this will have a lot of environmental impact on the inhabitants of the area. Also, the roads in the area are not spared from destruction too.

Fig. 4, shows satellite imagery and 3D image of Avbiama pit. This burrow pit is close to residential area, the environmental impact on the people and the environment cannot be denied. Some of the environmental problems include destruction of the road, noise and air pollution among others.

Fig. 5, satellite imagery and 3D image of Ihimwinhin pit. The environmental degradation is similar to that of Avbiama pit area in Figure 4

#### 4. CONCLUSION AND RECOMMENDATIONS

This paper investigated the geospatial assessment of the impacts of sand mining activities in Benin City, Edo State, Nigeria. It is imperative to know that housing and road construction activities will always be part of human, however, environmental sustainability should be prioritized. To this end, environmental degradation can be checked and reduced to an insignificant level to create a healthy and habitable environment. The challenges of sand mining and development can be controlled and reduced when government agencies responsible in regulating the activities of sand mining sit up to do their jobs.

It is against this background that the following is recommended; there should be proper and urgent environmental education of the sand miners about the fragile nature of the environment by the government. Similarly, the government regulatory body should ensure that Environmental Impact Assessment (EIA) is carried before mining pits are approved for mining activities. Also, the relevant authorities (inclusive but not limited to Edo State Ministry of Environment) should ensure that reclamation policies are strictly adhered to. Furthermore, the government should ensure authorization and issuance of permit authorization to all sand mining pits before mining commences. Mitigation measures such as proper recovery plan and awareness on environmental degradation should be highly advocated and promoted. Lastly, there should be a proper collaboration between the government, communities and sand miners that will climax into a sustainable environment devoid of environmental degradation.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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