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GIS AND REMOTE SENSING ANALYSIS OF SAND MINING ACTIVITIES IN YENAGOA: IMPLICATIONS FOR SHORELINE STABILITY

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Abstract: This study examines the impact of sand mining activities on the environment and host communities within Yenagoa using GIS and remote sensing techniques. Two zones, Famgbe and Obogoro communities along the Ikoli river and Tombia and Agudama-Ekpetiama communities along River Nun, were assessed in terms of environmental, infrastructural, and ground damage. Onsite observations, satellite imagery, and land use maps were used to analyze the damages caused by mining activities such as dredging and end-use activities such as filling and construction. Results reveal a direct link between the sand mining activities and damages to infrastructure, the natural environment, and shoreline migration. There is an increase in bare land and river expansion with increasing mining sites and dumpsites over the years. The study concludes that shoreline erosion has resulted from these activities, which are carried out indiscriminately in the study area without adequate licensing or monitoring. The findings of this study can serve as a basis for regulatory authorities to develop policies that protect the environment and host communities from the negative effects of sand mining activities.

Keywords: sand mining, GIS, remote sensing, environmental impact, infrastructure damage, shoreline migration.

1. INTRODUCTION

The need for the expansion of towns and cities is increasing rapidly as population grows around the world, as such, there is a high demand for fill material and construction sand. In order to expand, cities like Yenagoa located in a delta must reclaim land from vast swamps and marshes surrounding it. The primary source of construction sand/fill material in the Niger Delta is from sediments deposited by rivers and creeks around communities. Consequently, the mining of sand from these rivers and creeks and related activities put a lot of burden on the riverbanks as well as on the host communities, worse still is the indiscriminate nature of these mining activities which has posed danger on the ecosystem, existing infrastructure, life and livelihood Sand is a key material required for construction. It is also used as filling material for the reclamation of wetlands, as such, in most coastal communities of the Niger Delta, sand mining from the riverbed has become a primary source for generating income for the populace (Naveen, 2012; Tesi *et al*., 2018; Byrnes *et al*., 2004). The chain of activities of sand mining are considered to include those at the extraction site through the deposition and finally the lifting/transportation by heavy duty vehicles (Naveen, 2012).

Sand deposits usually occur in different amounts and particle sizes ranging from fine to coarse, this largely depends on the prevailing sedimentary conditions of the channel from which it is deposited like sinuosity and flow velocity. River sand mining activities are not new to Yenagoa and its surrounding coastal communities, but following the creation of Bayelsa state in 1996 and the consequent population explosion there has been a progressive surge in the demand for sand over the years for the purpose of construction and other industrial uses. Unfortunately, the activities of sand miners have gone largely unregulated by the government, even in cases where there are some regulations the government is yet to enforce same for the sake of the environment. With an estimated 16 million housing deficit (Ezekiel 2010; Isah, 2011) and the need for infrastructural development in Nigeria, there will continue to be great demand for sand and other construction materials especially in developing areas like Yenagoa (Omole and Ajakaiye, 1998).

Sand mining is either done manually or mechanically depending on the volume of sand required, the manual method involves diving and scooping the sand with metal buckets and emptying same into a boat, whereas the motorized method is use of either a mobile dredger or a stationed dredger.

The effect of indiscriminate sand mining on the environment cannot be overemphasized. Some recorded ecological implications include altered channelization of the river, destruction of vegetation, erosion along the valley side slopes, destruction of critical infrastructure such as bridge abutments and roads (Mbaiwa, 2008; Lawal ,2011)

This study integrates GIS and remote sensing data to investigate shoreline changes and some environmental implications across some communities along the Ikoli River and River Nun due to sand mining activities between 1990 and 2020.

2. MATERIALS AND METHODS

2.1 Study area

The study covers two zones within Yenagoa local government area of Bayelsa state (Fig. 1). The first zone is Famgbe and

Obogoro communities situated along Ikoli river and lying within latitude 4°55'0’’ N and longitude 6°15’0’’ E (Fig. 2a). The second zone covers Tombia and Agudama-Ekpetiama communities situated opposite each other along River Nun and lying within longitudes 6^0 15’0” and 6^0 15’30” East of the prime meridian and latitudes

5^0 00’0” and 4^0 59’30” North of the equator (Fig. 2b).

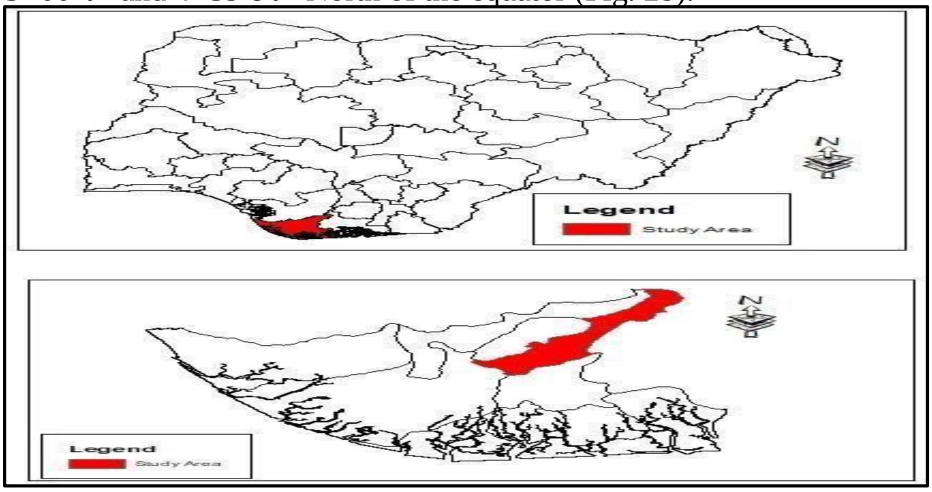

Fig. 1. Map indicating study area

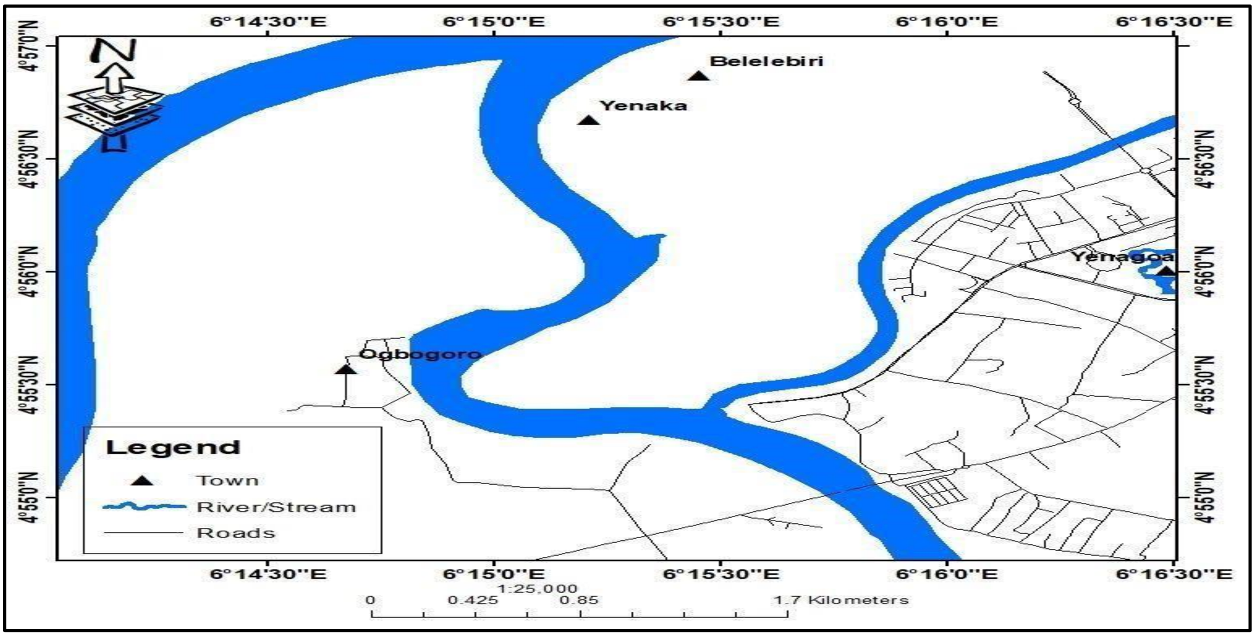

Fig. 2 a . Zone one communities along Ikoli River

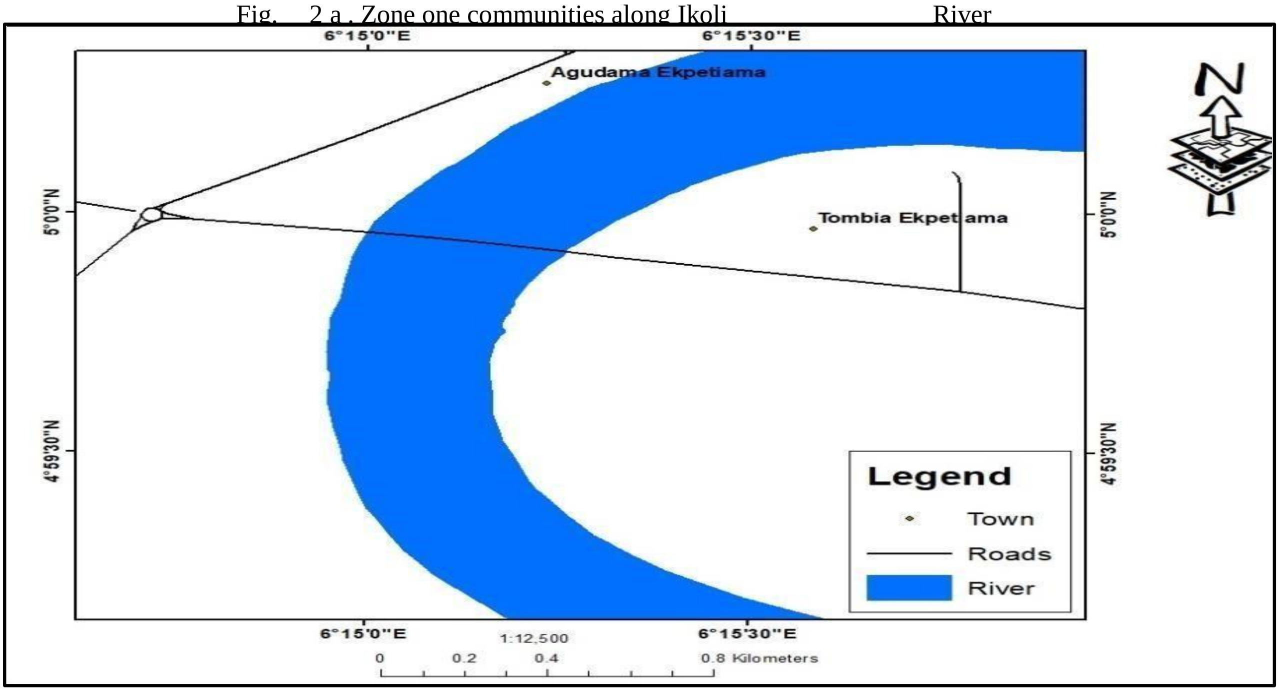

Fig. 2b. Zone two communities along River Nun

2.1 Physical onsite Observation

Onsite assessment of the environmental impact of mining activities on the shoreline was done, from which images were obtained and soil types determined in the field to guide satellite data.

2.2 GIS and Remote Sensing data

Landsat 5 (1990), Landsat 8 (2013) and Landsat 8 (2021) Explorer images were downloaded from https://landsate usgs.gov (Table 1). Spatial locations of communities in Yenagoa were established using Garmin 72 GPS device. Satellite images were downloaded from Google Earth for 1990, 2013 and 2021 with the aid of a universal map downloader, the administrative map showing political boundaries and roads were then digitized.

Table 1. Satellite data collected

Satellite Data	Date	Spatial Resolution (m)	Source
Landsat 5	28/02/1990 Path: 189, Row: 57	30	https://landsate usgs.gov
Landsat 8	26/12/2013 Path: 189, Row: 56	30	https://landsate usgs.gov
Landsat 8	6/1/2021 Path: 189, Row: 56	30	https://landsate usgs.gov
Google Earth Imagery	14/12/1990	3	https://google.com/earth
Google Earth Imagery	10/02/2013	3	https://google.com/earth
Google Earth Imagery	05/01/2021	3	https://google.com/earth

3. RESULTS AND DISCUSSIONS

3.1 Onsite observations

Soils around the riverbanks of the study area ranged from silty-clay or sandy-clay according to field tests done in accordance with BS5930:2015. These soils are weak and normally consolidated making them susceptible to rapid disintegration and erosion upon wetting and or stressing.

A study of mining sites revealed that damages to critical infrastructures (Fig. 3a). In some areas, erosion has been triggered near bridge abutments (Fig. 3b). These damages were observed to occur as moving heavy trucks loaded with tonnes of mined sand continuously exert excess weight or stress on both road infrastructure and weak grounds.

Fig. 3a. Road damage at Tombia caused by heavy Fig. 3b. ground damage near Tombia – Agudama vehicles laden with tonnes of sand Ekpetiama bridge caused by heavy vehicles laden with tonnes of sand

From physical observations also, it was noticed that some of the mining (both manually and mechanically operated) were sited relatively close to the shoreline. It is common knowledge that the sand extraction process creates holes (usually with unprotected walls) on the bottom of the river. These unprotected walls start falling off or collapsing and this extends to the shoreline causing shoreline collapse or erosion. The Figs. 4a & 4b show this scenario as captured at Famgbe and Obogoro communities, respectively.

Fig. 4a. River shoreline erosion due to dredging near to Fig. 4b. River shoreline erosion due to dredging near shoreline at Famgbe community to shoreline at Obogoro community

3.2 Shoreline study using GIS and Remote Sensing

The land use maps generated from the integration of remotely sensed data with thematic features from land use models using satellite imagery for 1990, 2010, and 2020 (zone two) are presented as Fig. 5.

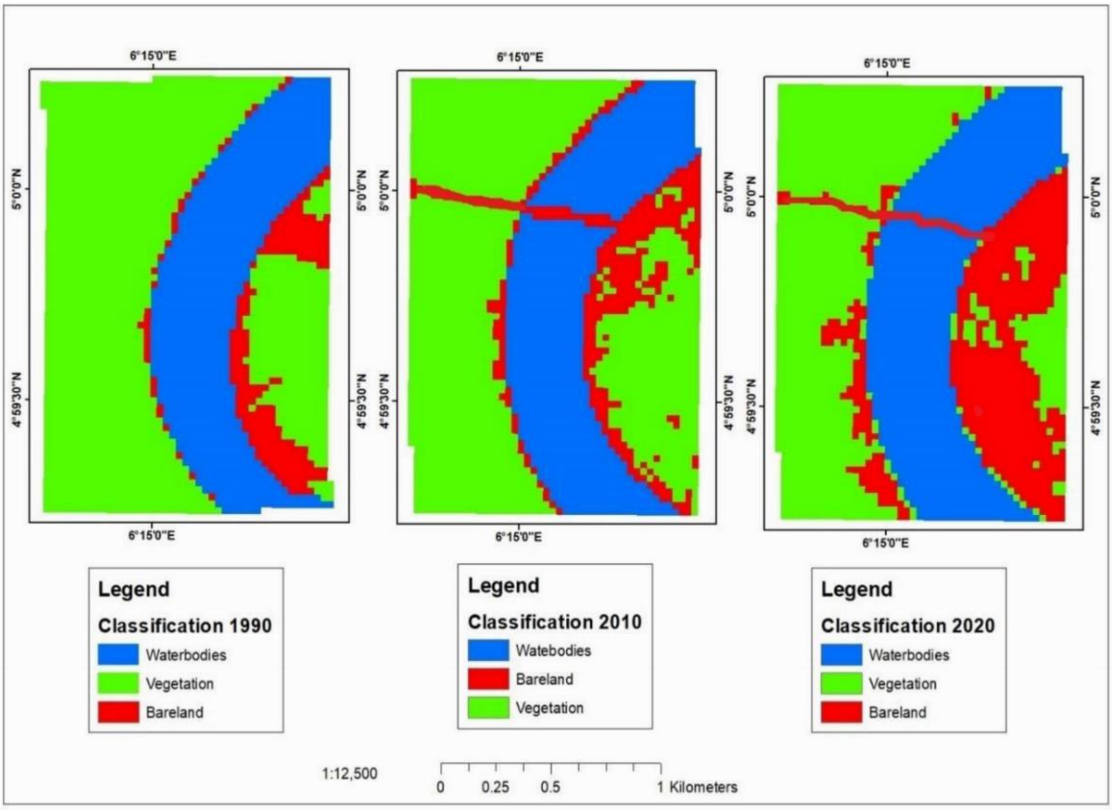

Fig. 5. Land use classification of zone two for 1990, 2010, and 2020.

The satellite imagery was processed and classified using a supervised classification scheme by assessing landuse patterns and categorizing them into three classes, namely water bodies, vegetation, and bare land areas based on the area covered. For each class, the estimated values for area covered are presented in Table 3 and graphically shown as Fig. 6. These values are also presented in terms of the percent area covered in Table 4.

Table 3. Statistics of land use for 1990, 2010, and 2020

Classification	1990 (km^2)	2010 (km^2)	2020 (km^2)
Waterbodies	0.75	0.81	0.89
Vegetation	1.47	1.31	0.95
Bareland	0.24	0.34	0.62
Total km^2	2.46	2.46	2.46

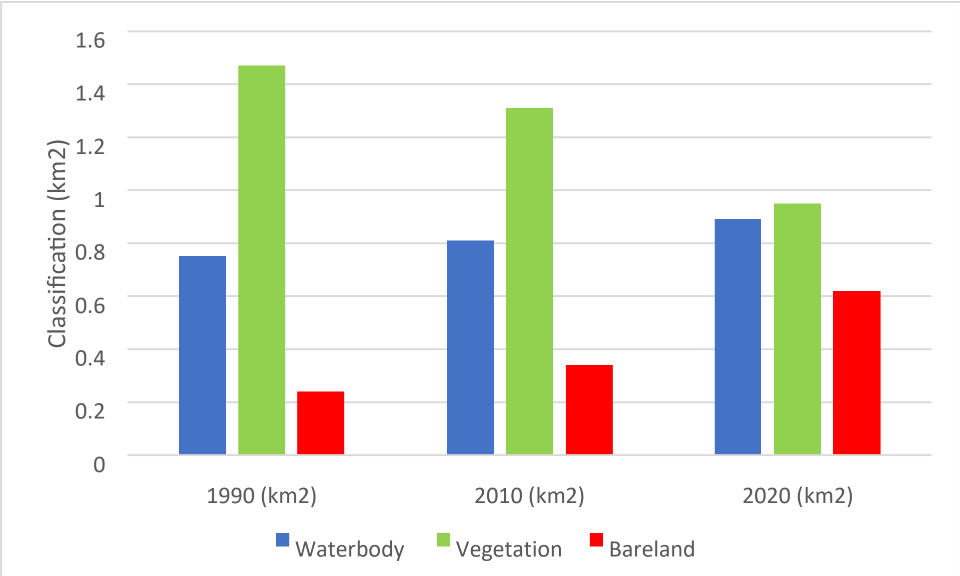

Fig. 6. Land use change from 1990 to 2010 and 2020. Table 4. Percentage of land use for 1990, 2010, and 2020

Classification	1990 (%)	2010 (%)	2020 (%)
Waterbodies	31	33	36
Vegetation	39	35	26
Bare land	20	28	52

The data presented in Tables 3 & 4 and Fig. 6 show clear evolution of all the three classes of waterbodies, vegetation, and bare land over the years. There is an increase in the measured area occupied by waterbodies from 1990 to 2020. This is an expansion of the river width as the banks continued to suffer erosion caused partly by the activities of sand mining. While vegetation area continued to decrease, the bare land area increases. Understandably, the vegetation area was depleted as the river sand mining business expanded, thus, more land area is captured as bare land. Although vegetation depletion could also result from other activities, e.g., burning. However, a walkover these sites was done and observation confirmed that all bare land areas were those occupied by sand mining activities.

3.2.2 Shoreline and sand dumpsite evolution

Shoreline evolution maps and historic images of sand dumps for each of the zones under the study area are presented as Figs. 7a & 7b, respectively for zone one and Figures 8a and 8b, respectively for zone two.

Both zones of the study area have shown shoreline changes as well as sand dumpsites increasing over the years. This notwithstanding, there is no clear relationship between the shoreline changes and the sand dumpsites increase. It was expected that shoreline erosion leading to river width expansion should progress on the side of the river where more extraction sites are located, but unfortunately, as indicated in Figs. 8a and 8b, the shorelines have rather migrated westward while mining took place on the eastern side of the river.

Nevertheless, increasing river sand mining sites viz-a-vis extraction holes can also accelerate its impact on the river shoreline.

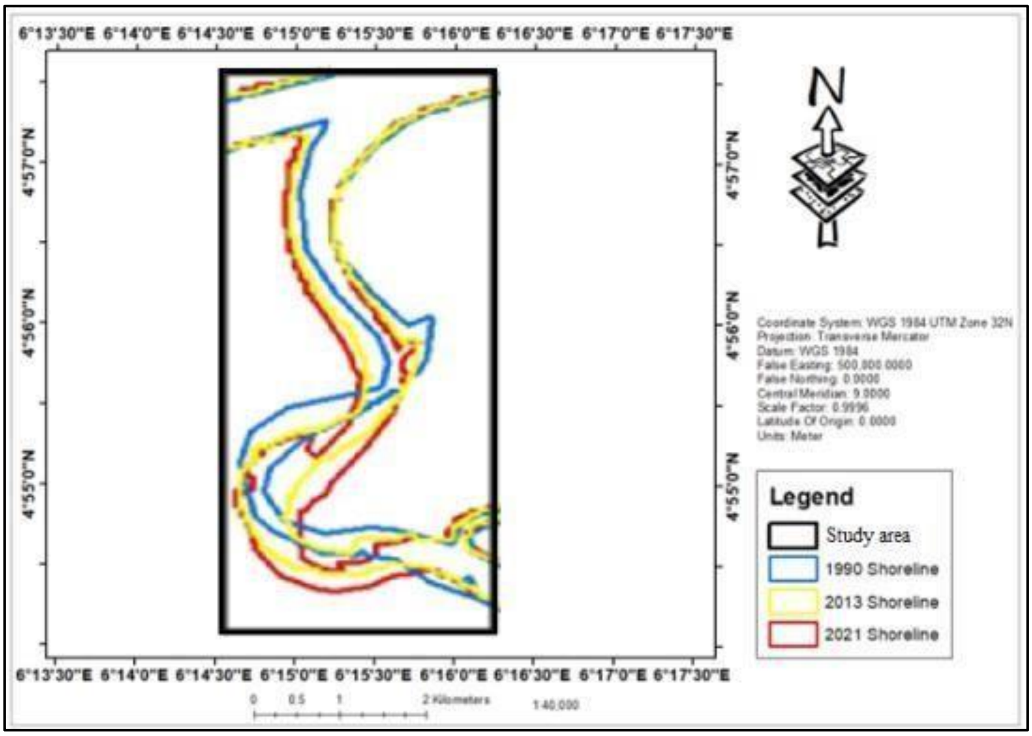

Fig. 7a. Zone one shoreline changes from 1990 to 2021

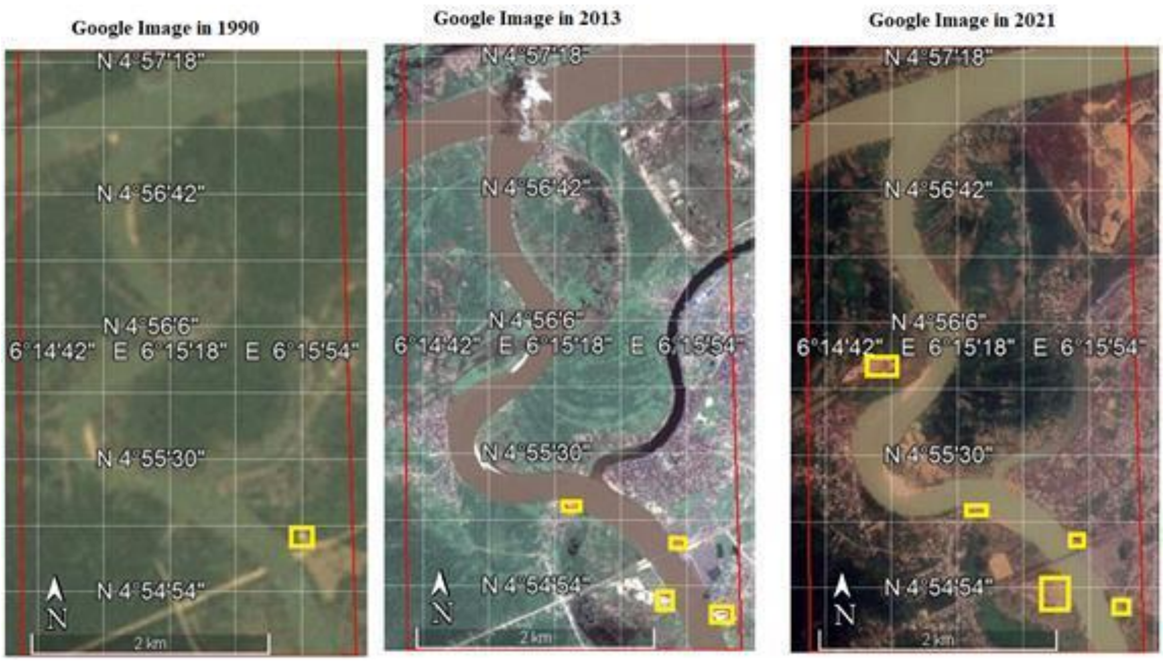

Fig. 7b. Zone one google earth historical images showing sand dumps from 1990 to 2021

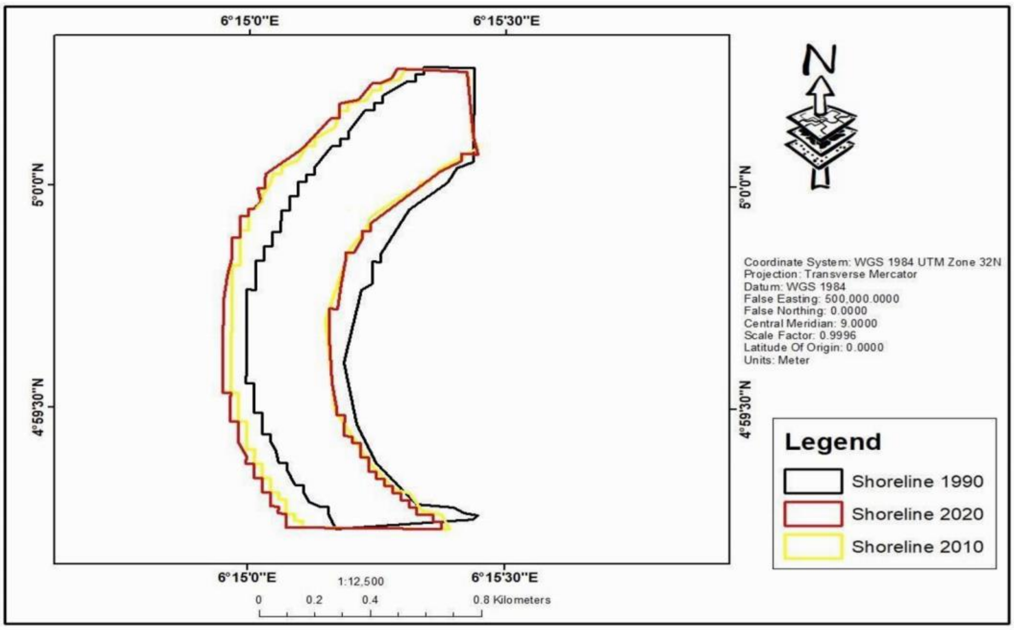

Fig. 8a. Zone two shoreline changes from 1990 to 2020

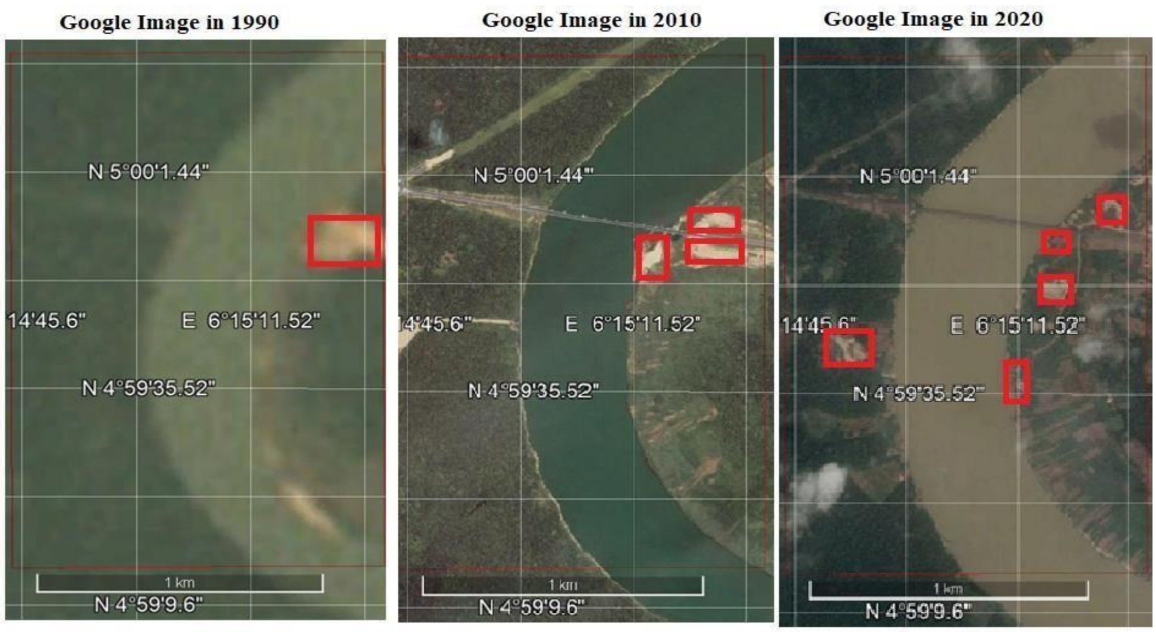

Fig. 8b. Zone two google earth historical images of sand dumps from 1990 to 2020

The shoreline and sand dump evolutions in terms of land area covered are summarized in Table 5. The estimated values are graphically shown as Figs. 9 to 11.

Table 5. Shoreline and sand dumpsite areas changes in the two zones under study

	Zone One (Ikoli river)			Zone Two (Tombia – Agudama Ekpetiama river		
Zone two	**1990**	**2013**	**2021**	**1990**	**2010**	**2020**

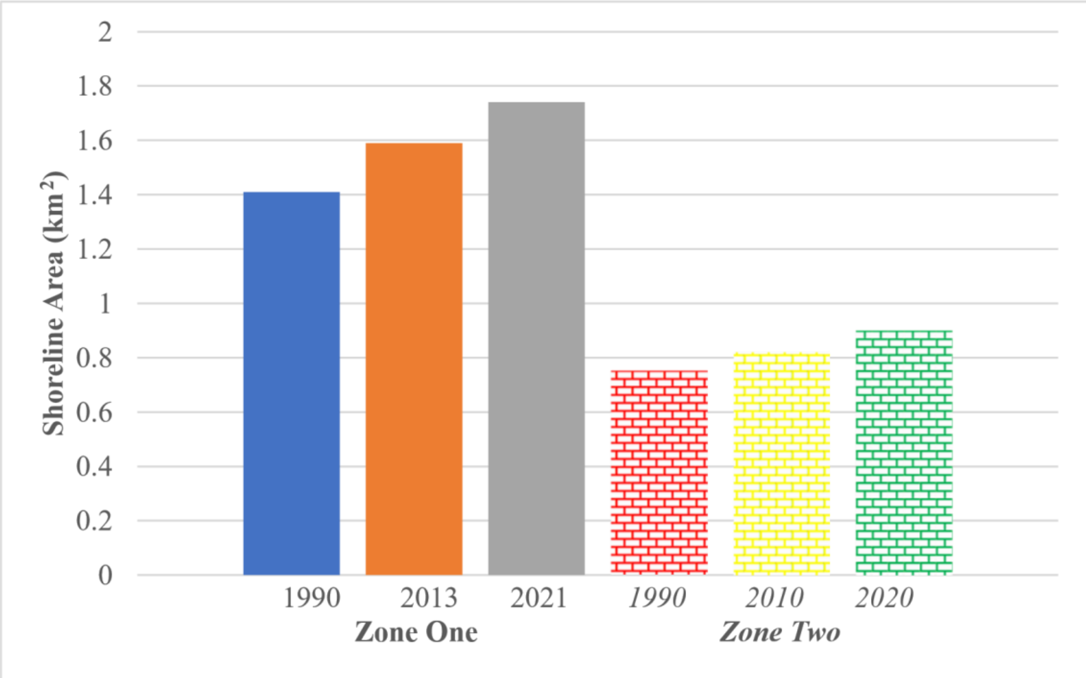

Fig. 9. Shoreline changes from 1990 to 2021

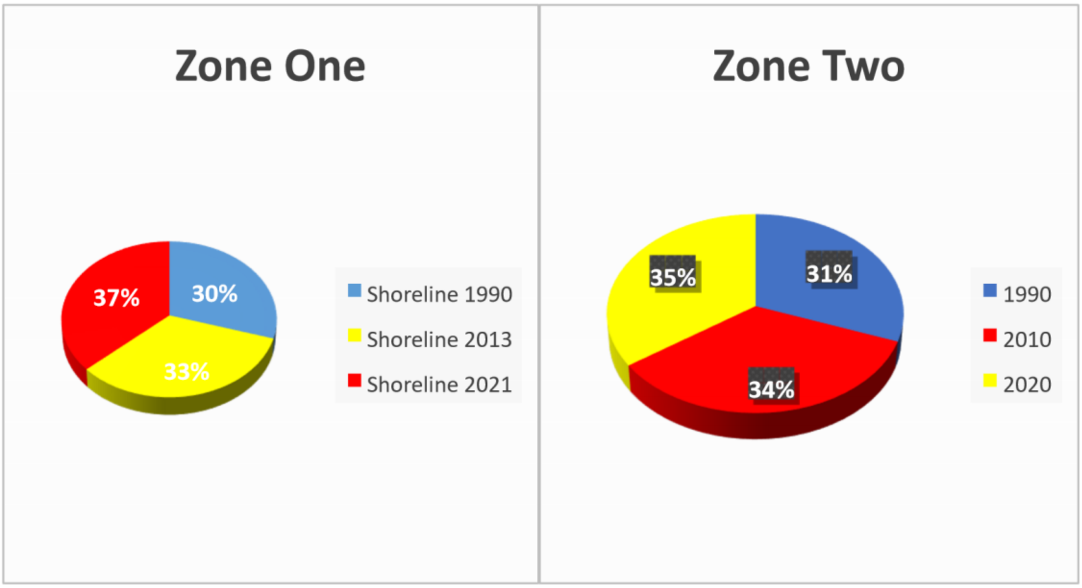

Fig. 10. Percentage shoreline changes from 1990 to 2021

Shoreline area (km^2)	1.41	1.59	1.74	0.75	0.82	0.9
% Shoreline area	29.75	33.54	36.71	31	34	35
Sand dumpsite (m^2)	90.2	212.21	489.23	1420.11	2856.23	3200.12

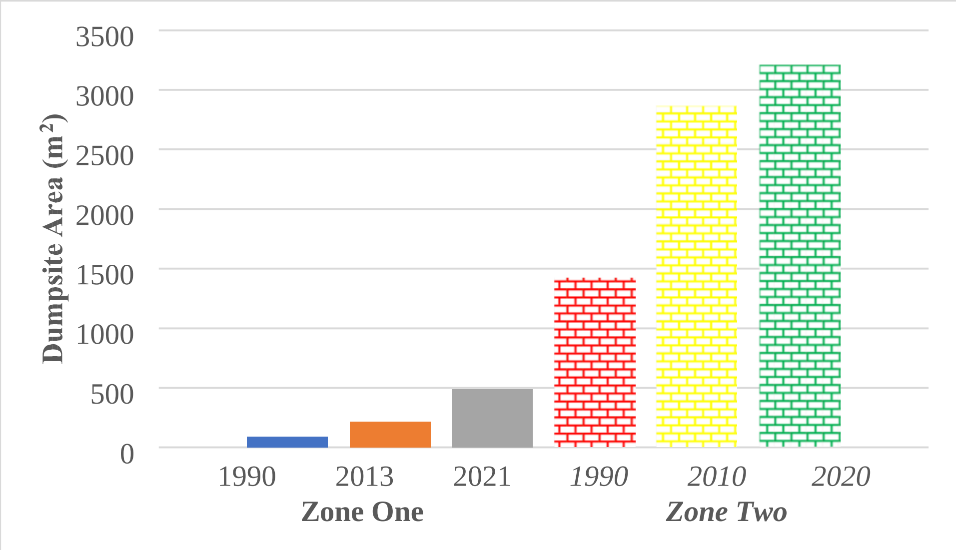

Fig. 9. Dumpsite area changes from 1990 to 2021

Zone One shows a wider shoreline area than Zone Two while the reverse is the case for dumpsite area. As earlier stated, there are increases over the years, in shoreline and dumpsite areas for both zones under study. While shoreline increases of 12.77% and 9.43% between the years considered were recorded in Zone One, increases of 9.33% and 9.73% were recorded for Zone Two. On the other hand, the increases in dumpsite areas were 135.27% and 130.54% for Zone One and 101.13% and 12.04% for Zone Two. Yet, less sand dumpsite area has resulted in Zone One than in Zone Two. That is, more river sand mining takes place in Zone Two. This might have been possible because of the difference in the extraction methods common in each zone, and the availability of free land space. While manual extraction method is used in Zone One, the mechanical extraction method prevails in Zone Two.

On the contrary, the rate of increase of dumpsite area did not directly relate to the rate of increase in shoreline area for both zones under consideration. This suggests that river sand mining is not solely responsible for shoreline evolution. Other processes prevalent within the river system (e.g., wave actions, erosion and accretion, etc.) contribute to its shoreline evolution.

4. CONCLUSIONS

The study aimed to establish the adverse impact of river sand mining activities on some communities using GIS and remote sensing techniques, and onsite observations. Consequently, the following conclusions have been reached:

Onsite observations revealed irregular grounds and damaged roads around areas were river sand mining activities take place. These were the impressions of heavy-laden trucks used for the transportation of mined sands to end users. The activities of river sand mining are carried out indiscriminately in the study area. It was discovered from interactions with operatives that licenses were almost not necessary to carry out these activities, and even where licenses are obtained, there are no regulators visiting to monitor such activities. Shoreline erosion has resulted from these activities and to some extent shoreline migration has increased as sand mining sites and dumpsites increased over the years.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

British Standards Institute (BSI) 2015 BS5930 Code of Practice for Site Investigations (London: British Standard). P. 134

Byrnes M. R., Hammer R. M., Thibauta T. D & Snyder D. B. (2004). Potential effects of sand mining on physical processes and biological communities offshore, New Jersey, USA. *J. Coastal Res.*, 20(1): 25-43.

Ezekiel, E. (2010). Nigeria needs N45 trillion to tackle housing deficit-FMBN. In *Nigerian Business Forum*. 18(1): 27-44.

Feola, A., Lisi, I., Salmeri, A., Venti, F., Pedroncini, A., Gabellini, M., & Romano, E. (2016). Platform of integrated tools to support environmental studies and management of dredging activities. *Journal of Environmental Management*, *166*, 357-373.

Isah, R. (2011). Nigeria: Making housing fund contribution national agenda. [Online] Available at: http://allafrica.com/stories/201106240782.html (June 30, 2011).

Lusiagustin, V., & Kusratmoko, E. (2017). Impact of sand mining activities on the environmental condition of the Komering river, South Sumatera. In *AIP Conference Proceedings*. 18(1): 30.

Mbaiwa, J. E. (2008). *Tourism development, rural livelihoods, and conservation in the Okavango Delta, Botswana*. Texas A&M University, p. 23-25.

Naveen, S. M. (2012). Environmental impact of soil and sand mining: A Review. *Int. J. Sci. Environ. Technol, 1*, 125-134

Omole, D., & Ajakaiye, O. (1998). Environmental Externalities and Sustainable Urban development: who bears environmental costs. *Sustainable physical development in Nigeria, Ibadan: Nigerian Institute of Social and Economic Research*, p. 115-132.

Lawal, P. O. (2011). Effects of sand/gravel mining in Minna Emirate area of Nigeria on stakeholders. *Journal of Sustainable Development*, *4*(1), 193.

Tesi, J. A., Tesi, G. O., & Enete, C. I. (2018). Assessment of the socio-economic impacts of river sand mining along the Warri River, Delta State. *FUW Trends in Science and Technology Journal*, *3*(1), 56-59.