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The Impact of Sand Mining on Riparian Areas of Eyaa, Onne, Nigeria

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Abstract
Excessive sand mining in the Eyaa River, Onne, Rivers State, Nigeria has led to severe cases of land degradation manifesting as river bank erosion of riparian areas in Eyaa, Onne. An estimated land area of 142,000m^2 (equivalent to about 497,000m^3) has been lost in the past five years (2010-2015) which has resulted in widening of the stream channel to more than double its original width prior to the commencement of sand mining in 2006. Instream sand mining leads to depletion of sand on the stream bed ultimately deepening the stream channel. Results of Particle Size Distribution tests of soils within 2.5-3.5m horizon revealed 6.8% fine sand, 61% medium sand and 31.9% coarse sand. Crumb tests results classify the soils as highly dispersive soils. This explains the undercutting and the eventual collapse of the river banks observed in the study area which poses serious threats to farmlands and built up areas within the riparian areas of the Eyaa River. The results of the study revealed that instream sand mining leads to the destruction of riparian habitat occasioned by changes in channel morphology and hydraulics, lowering groundwater level thereby affecting groundwater system in Eyaa community. A rapid collapse of the river banks initiates the development of gully heads and the current rate of land loss observed around the banks of the Eyaa River will potentially extend into the Eyaa community within 5 years if not checked. Moreso, collapsed stream banks and dredged spoils increases the turbidity of the river with severe consequences for aquatic species.
Keywords: Riparian, Dispersive, Crumb Tests, Channel Morphology, Hydraulics, Gully.

1.0 Introduction:

Sand mining is the harvesting of sand grade materials from the river bed for various engineering purposes. Instream mining results in channel instability through the direct disruption of pre-existing channel geometry or through the effects of incision and related undercutting of banks (Collins and Dunne, 1986). Mining also aggravates widespread instability because the discontinuity in the sediment supply-transport balance tends to migrate upstream as the river bed is eroded to make up for the supply deficiency (Knighton, I984). Thus, sand mining from a relatively confined area, such as Eyaa River in Onne, Rivers State triggers erosion of bed and banks, which in turn, increases sediment delivery to the original site of sediment removal. The effects of this instream sand mining required continuous monitoring, and it took about a decade for the effects to be propagated along the river channel in measurable units. Mining may continue for years without apparent effects upstream or downstream, only to have geomorphic effects manifest later during high flows. Hence, rivers are often said to have 'long memories', meaning that the channel adjustments to instream extraction or comparable perturbations may persist long after the activity has ceased (Kondolf, 1997).

Population growth and the consequent demographic expansion in the Port Harcourt and its environs such as Eleme and Onne towns in Rivers State necessitates an increase in construction activities and therefore the demand for sand. Recently, there has been an increase in various civil engineering construction works around the study area; particularly the dualisation of the East-West Road, an interstate highway that links Rivers State with Akwa Ibom State which created a very high demand for sand during the past 10 years (2005-2015). This high demand makes sand mining a very profitable commercial venture; inducing sand miners to excessively harvest sand from the stream bed in Eyaa River. Sand mining in the area at present removes more sand grade material than it is being generated by natural processes and deposited by stream flow. This results in the lowering of the stream bed and the stream level, undercutting of the river banks and the eventual collapse of the side walls. Collapsing channel walls become sources of sediment supply, thereby increasing suspended sediment and turbidity which alters the physical conditions of the Eyaa River; thus becoming an unsuitable niche for a variety of organisms. The lowering of groundwater levels as a result of the deepening channel induces stress for riparian flora and a drop in the water table in Eyaa community. Many hectares of riparian farm lots and other riverside habitats are lost to riverside erosion; leading to a decline in biodiversity and agricultural productivity of the study area. These processes that widen the river channel, initiates the development of gullies within the riparian corridor. Hence, instream sand mining alters the geomorphology of the Eyaa riparian areas from a narrow, shallow stream channel to a wide river system, bringing about irreversible changes within the physical environment.

2.0 Background to the study area:

The Eyaa river in Onne, Rivers State, is geographically located between longitudes 7.161^o - 7.171^o and latitudes

4.739° - 4.753°, however, the river continues its course southwards joining the Onne river which eventually empties into the Bonny River and then the Gulf of Guinea. The study area covers about 179.40 hectares, situate on the dry deltaic plains geomorphic unit of the Niger Delta and underlain by the Benin Formation. The surficial Quaternary deposits in the study area consist of alternating fine medium grained Sands, Silts and subordinate lensoid Clays (Amajor, 1991). These sand deposits have distinct properties that differentiate them from those of the Benin Formation (Abam, 2007); and have been quarried extensively for building purposes (Akpokodje and Etu-Efeotor, 1987).

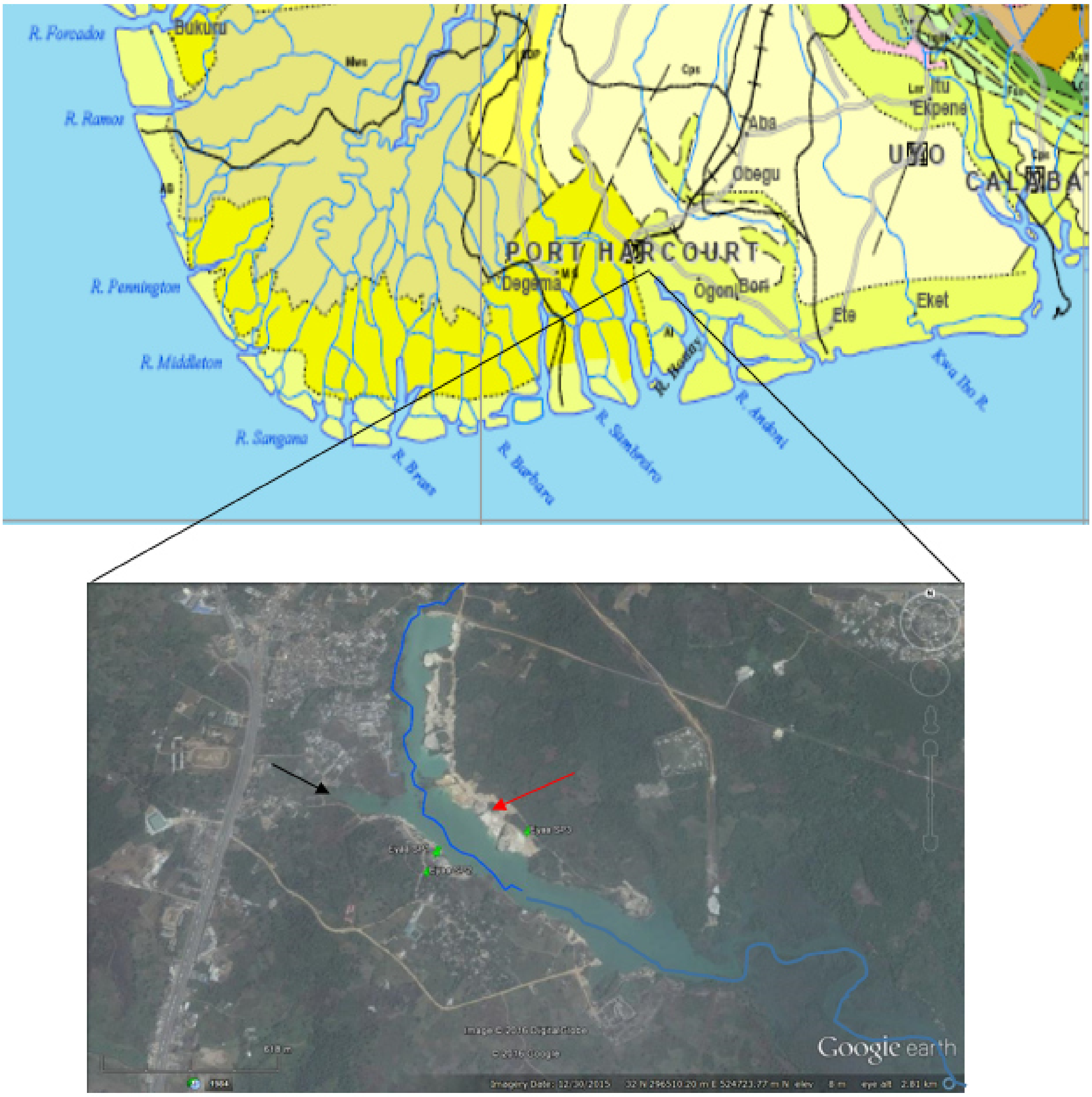

Figure 1: NGSA Map of Southern Nigeria, inset (imagery) shows instream sand mining on the Eyaa River, Onne, Rivers State. Red arrow shows mined sand stockpile on the banks of the River, black arrow show prograding gully heads and green pins show soil sampling points.

Table 1. Geologic Units of the Niger Delta

Geologic Unit	Lithology	Age
Alluvium (General)	Sand, Silt, Clay	
Freshwater Backswamp meander belt	Sand, Clay, some Silt, Gravel	
Saltwater Mangrove Swamp and Backswamp	Medium-Fine Sands, Clay and some Silt	Quartenary
Active/Abandoned Beach Ridges	Sand, Clay and some Silt	
Sombreiro-Warri Deltaic Plains	Sand, Clay and some Silt	
Benin Formation (Coastal Plain Sand)	Coarse to Medium Sand, subordinate Silt and Clay lenses	Miocene- Recent
Agbada Formation	Mixture of Sand, Clay and Silt	Eocene- Recent
Akata Formation	Clay	Paleocene

After Akpokodje, 1989.

3.0 Materials and Methods

The lithology of the study area was established through manual augering of boreholes situated at the banks of the river (see Fig 1) and advanced to a maximum depth of 3.5m. Soil samples were obtained from the augered boreholes at 0.5m intervals and at horizons were there were obvious lithological changes. Samples were visually assessed, described on site and sent to the laboratory for Particle Size Distribution analysis and Crumb tests using BS 1377 (1990) and ASTM D6572, (2000) standard methods respectively. Archival Google Earth satellite imageries of the study area from 2006 to 2015 were obtained and critically evaluated to establish the expansion of the Eyaa river channel and the changes that have taken place within the riparian corridor during the period. A change detection analyses of the imageries were carried out, establishing a progressive variation in riparian morphology and channel size within the ten year period. In carrying out this multi-temporal analysis, the imageries had to be of the same scale and sensor to ensure comparability of the various aspects.

4.0 Results and Discussion.

4.1 Particle Size Distribution: PSD from the study site reveals a poorly graded, well sorted sands, with 6.8% fine sand, 61% medium sand and 31.9% coarse sand; with very little fines (1.2-0.1% passing through 0.075mm sieve). The sands are therefore classified as SP (Poorly Graded) under the Unified Soil Classification System (U.S.C.S). The gradation patterns and particle size distribution curves are shown in figure 2.

Table 2: Particle Size Distribution of Soil Samples in Eyaa

Location No/Coordinates	Bore-Hole No.	Depth (m)	Percentage Passing Sieve diameter (mm)						% of Fine sand	% of Medium sand	% of Coarse Sand
			2	**1**	**0.5**	**0.25**	**0.15**	**0.075**			
1	**ESP1**	0-0.5	97.6	91.5	60.0	14.6	2.8	0.5	8.5	60	28.6
296167, 524643		0.5-1	97.6	90.3	63.3	15.9	2.4	0.1	9.9	60	27.6
		1-1.5	97.4	86.6	62.7	18.5	3.0	0.3	9.7	60	27.4
		1-5.2	93.2	76.2	50.9	13.2	2.5	0.3	7.7	50	35.2
		2-2.5	90.7	70.3	46.0	12.3	2.8	1.2	4.8	45	40.7
		2.5-3	99.9	92.0	63.0	16.8	2.8	0.2	6.8	61	31.9
2	**ESP2**	0.5-1	99.9	92.0	63.0	16.8	2.7	0.2	9.8	60	39.9
296133, 524569		1-1.5	99.3	91.2	57.5	2.8	2.2	0.6	7.5	59	32.3
		1.5-2	99.2	89.9	58.0	13.8	2.3	0.5	9.5	57	32.2
		2-2.5	99.0	88.6	57.4	14.6	3.3	1.3	7.7	55	33.8
		2.5-3	96.3	81.0	57.7	16.9	4.5	1.8	7.2	51	36.3

The PSD displays a uniform gradation Curves shown below

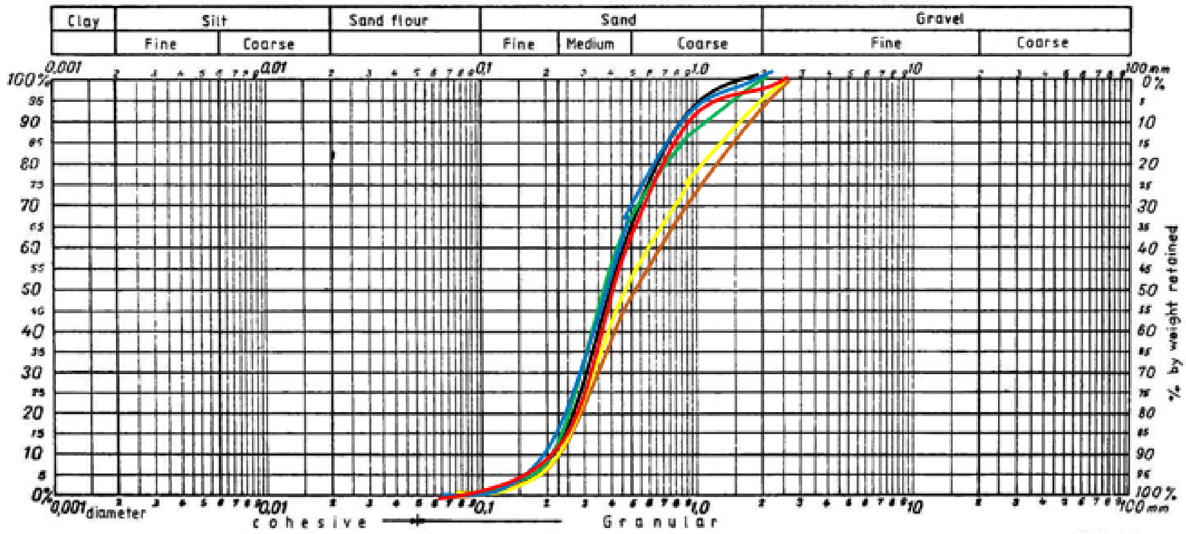

Figure 2: Particle Size Distribution Curves of Borehole ESP1 (6 layers 0.0 - 3.5m)

4.2 Site Lithology and Soil Properties.

Subsurface lithology of the riparian corridor of the Eyaa River, reveals a greyish brown sequence of silty sands at the surface; and coarsening downwards into greyish yellowish, friable, angular to sub-angular sands with little or no fines at depths of 3m and below (see figure 3 for lithologic logs). The soils are cohensionless; which explains its erodibility and low resistance to erosive forces of the river, resulting in undercutting and collapse of the bank walls; ultimately widening the channel. This inherent susceptibility of the soils within the riparian corridor to erosion and failure, facilitates the development of active gully heads that are extending to community farm-lots and neighbourhoods (see figure 1).

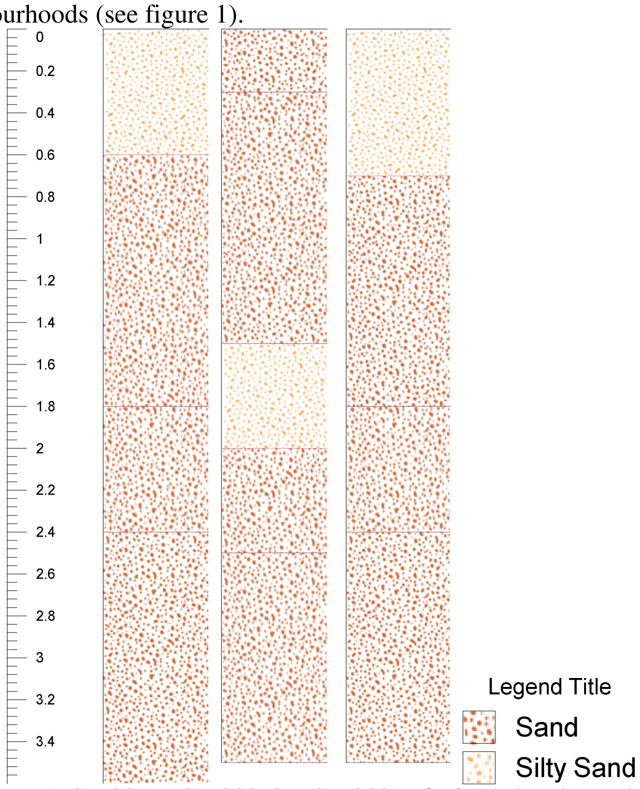

Figure 3: Lithologic logs (ESP-001, ESP-002 & ESP-003) of triangulated Boreholes (see fig.1) on the banks of Eyaa River, depth scale in metres.

4.3 Susceptibility of Eyaa Soils to Dispersion and Failure.

Dispersive soils are susceptible to erosion as they tend to deflocculate in the presence of flowing water. Soil samples collected from 2.5m and below displays Grade 4 Dispersability (see table 3). This probably explains the Eyaa River bank failure due to undercutting. Note that the deepening of the river channel due excessive sand mining lowers the water level; and the surface of the flowing river abrades the 2-3m horizon of the soil profile causing soil dispersion, erosion and ultimately failure. This undercutting initiates bank failure and the formation of gullies.

Table 3: Results of Crumb Tests from boreholes along Eyaa river.

Bore-hole No.	Depth (m)	Reaction Description	Dispersability	Grade
ESP1	0-0.5	No reaction crumbs slake but no sign of colloids in suspension	Non dispersive	1
	0.5-1	No reaction, crumbs slake but no sign of colloids in suspension	Non dispersive	1
	1-1.5	Slight reaction, A very slight cloudiness shown at water surface of crumb	Slightly dispersive	2
	1.5-2	No reaction, crumbs slake but no sign of colloids in suspension	Non dispersive	1
	2-2.5	Slight reaction. slight cloudiness shown at water surface of crumb	Slightly dispersive	2
	2.5-3	***Strong reaction, complete collapse, all the water becomes cloudy and colloidal. Cloud covers the bottom of the breaker usually as a thick skin***	***Dispersive 4***	***4***
ESP2	0.5-1	No reaction, crumbs slake but no sign of colloids in suspension	Non dispersive	1
	1-1.5	No reaction, crumbs slake but no sign of colloids in suspension	Non dispersive	1
	1.5-2	No reaction crumbs slake but no sign of colloids in suspension	Non dispersive	1
	2-2.5	Slight reaction, A very slight cloudiness shown at the water surface of the crumb	Slightly dispersive	2
	2.5-3	Slight reaction, A very slight cloudiness shown at the water surface of the crumb	Slightly dispersive	2

4.4 Change Detection Analysis of Imageries of study area 2006-2015.

One primary advantage of satellite remote sensing is the ability to show imageries of the same location of the earth's surface at different times. A multi-temporal analyses of the riparian corridor of the Eyaa River from 2006 to 2015 was an amazing technique that enabled the visual observation, detection and measurement of the changes that had occurred in the study area during the period. It facilitated the estimation of the aerial extent and volume of land loss within the corridor; by comparing and measuring the size of the stream channel on the imageries of the different years till 2015.

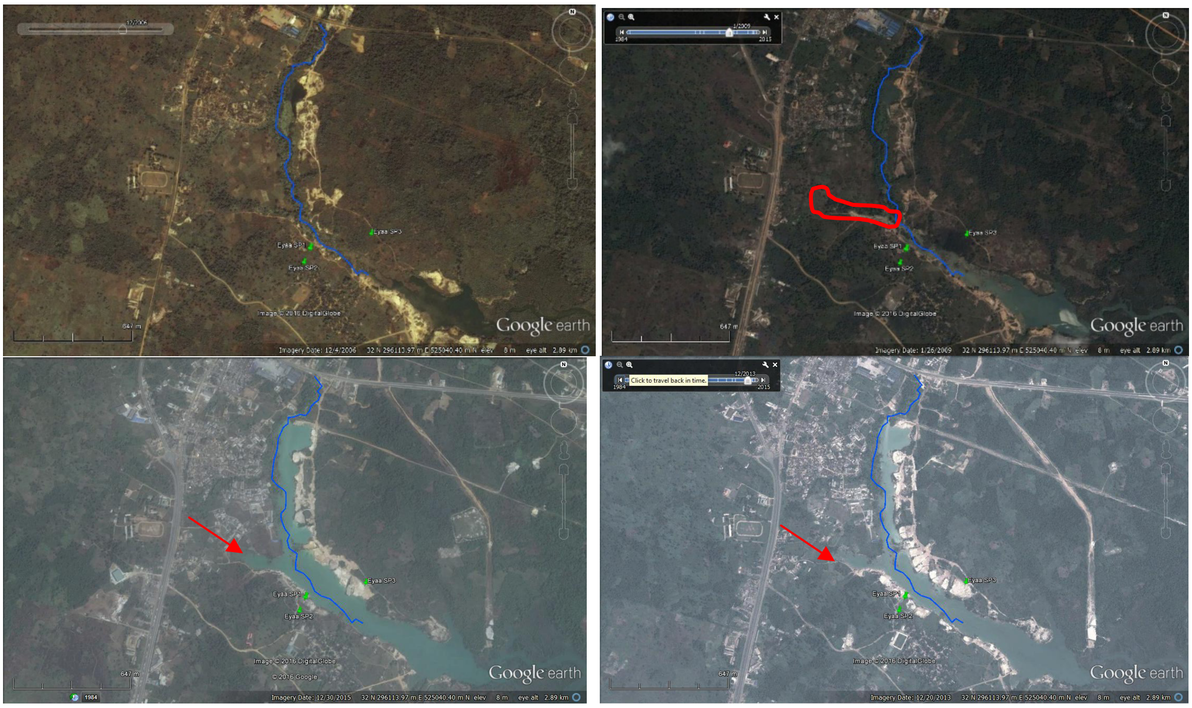

Figure 4: Archival imageries of the study site, clockwise from top, 2006, 2009, 2013 and 2015.

In figure 4 above, the riparian corridor in Eyaa appeared intact up till 2009, three years after the commencement of intensive sand mining. The widening and progression of the river channel northwards, towards the East-West interstate highway began in about 2011 and became evident by 2013. Old river channels with sandy sedimentary infills become sites for the easy progression of the gullies initiated at the bank of the river. Note the old river channel delineated in red in the 2009 imagery (not delineated in the 2006) being susceptible to erosion and presents the physical conditions for the initiation and development of gully heads (see 2013 and 2015 imageries, red arrows shows developing gully).

Figure 5: Clockwise from top, a gully head prograding towards Eyaa community. The red ellipse shows stumps of riparian zone trees that are now in the centre of the river due to erosion (disappearance of a community of riparian flora).

4.4.1 Estimated Land Loss within the Riparian Zone of Eyaa River 2006-2015.

Figure 6 below, illustrates the loss of riparian flora to river bank erosion due to sand mining; (A) depicts pre sand mining scenario with a low flow channel, an accumulation of sand/gravel (mid-channel) and an intact riparian corridor. While (B) illustrates a widened stream channel, collapsing banks and disappearance of the riparian vegetation. This typifies the scenario in the study area.

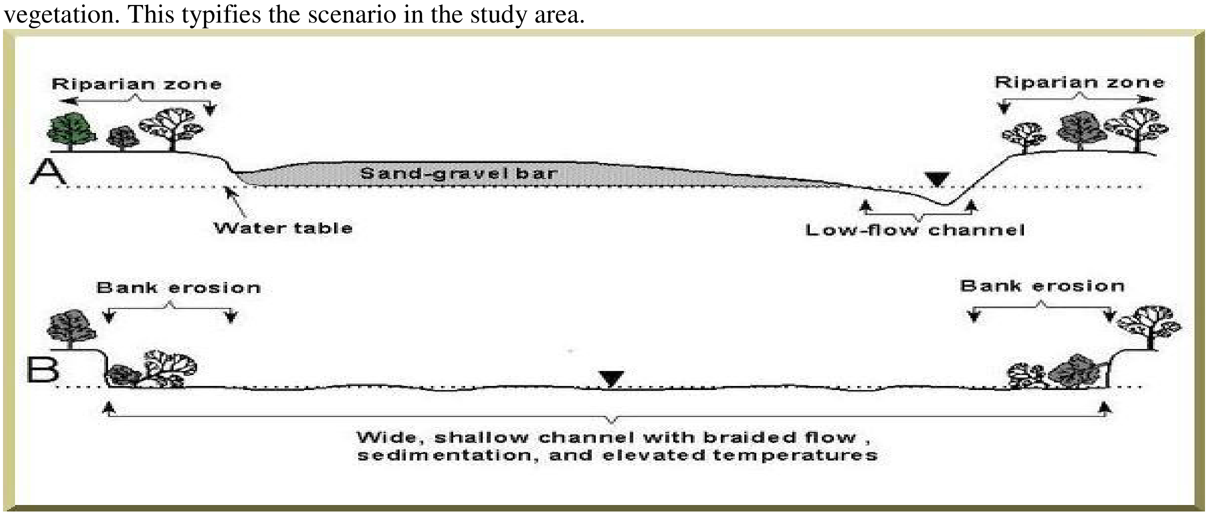

Figure 6 illustrates the impact of sand mining on riparian flora (after Stebbins, 2006).

The initiation and growth rate of gullies shown in figure 4, indicates that the Eyaa community structures and a segment of the East-West interstate highway are at risk to the prograding gully. Figure 7 shows the progressive area of land lost within the riparian zone of the Eyaa river within a 10 year period.

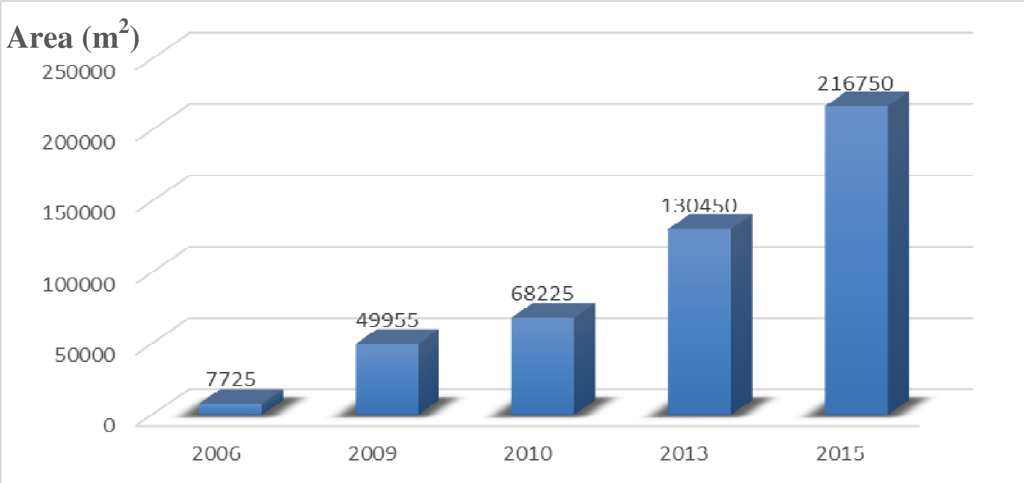

Figure 7: Progressive land loss within the riparian zone in the Eyaa community, for a ten year period.

5.0 Conclusion.

Unregulated sand mining in the Eyaa River, Onne, Rivers State, Nigeria has resulted to severe cases of land loss, gully development and a lowered water table. An estimated land area of 142,000m^2 (equivalent to about 497,000m^3 or 844,900 metric tonnes of soil) has been lost in the past five years (2010-2015). This has resulted in widening of the stream channel to more than double its original width prior to the commencement of sand mining in 2006. A healthy floral community and biodiversity within the riparian zone have also been lost to an excessive instream sand mining, ultimately deepening the stream channel. Furthermore, an increase in river turbidity affects the aquatic microflora and fauna; this will impact on the fishery resources of the river and the livelihood of the Eyaa community.

From the foregoing discussions, it is evident that excessive instream sand mining in the Eyaa River in Onne, Rivers State has presented more negative impacts on the community and environment than the economic gains made from sand mining; which makes it unsustainable. Furthermore, the widening stream channel has progressed to a little over 500m from the East-West interstate highway; and should this progression continue, then it will take just a few years for the gully head to advance to the road shoulder. It is therefore recommended that the regulatory agencies whose duty it is to oversee the extraction of various natural resources, particularly sand mining in inland areas should be more proactive in carrying out their oversight functions to enhance a sustainable future to all citizens.

References

Abam, T.K.S., (2007). Soil Exploration and Foundations in Recent Coastal Areas of Nigeria. *Bulletin of Engineering Geology and the Environment,* vol. 53, pp. 13-19.

Akpokodje, E.G. & Etu-Efeotor, J.O., (1987). The Occurrence and Economic Potentials of Clean Sand Deposits of the Niger Delta. *Journal of African Earth Sciences,* vol. 6 (1), pp. 61-65.

Akpokodje, E.G.,(1989). Preliminary Studies on the Geotechnical Characteristics Of the Niger Delta Subsoil. *Engineering Geology*, No. 26, pp247-257.

Amajor, L.C., (1991). Aquifers in the Benin Formation (Miocene – Recent), Eastern Niger Delta, Nigeria: Lithostratigraphy, Hydraulics, Water Quality. *Environmental Geology and Water Sciences*, vol. 17(2), pp.85-101.

American Society for Testing and Materials (ASTM), (2000). Standard Test Method for Determining Dispersive Characteristics of Clay Soils by the Crumb Test, ASTM D6572-00, ASTM International, Pennsylvania.

British Standards (B.S), (1990). Methods of Test for Soils for Civil Engineering Purposes. British Standard Institution (BSI), London.

Collins, B. & Dunne, T., (1986). Gravel Transport and Gravel Harvesting in the Humptulips, Wynoochee and Satsop Rivers. Grays Harbour County, Washington. Report prepared for Grays Habour County Planning and Building Department by Brian Collins and Thomas Dunne, Geologists Dept. of Ecology. L-808, Seattle, Washington.

Knighton, D., (1984). Fluvial Forms and Processes. Arnold Publishers, London. 320p.

Kondolf, G.M., (1997). Hungry Water: Effects of dams and gravel mining on river channels. *Environ. Manage,* 21: 533-551.

Stebbins, M., (2006). Can Gravel Mining and Water Supply Wells Co-exist. Maine: University of Maine News Reports, p.8.