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VULNERABILITY OF COMMUNITIES TO FLOOD HAZARD AND RIVERBANK EROSION ALONG RIVER NUN IN BAYELSA STATE, NIGERIA

Meshach Owho Ojile[*1], Elijah O. Ogwara[2]

[*1]Department of Environmental Management Faculty of Environmental Sciences Niger Delta University, Wilberforce Island PMB 071, Yenagoa, Bayelsa State, Nigeria

[2]ICT Unit, Niger Delta University, Wilberforce Island, Amassoma, Bayelsa State

ABSTRACT

Perennial flooding leading to riverbank erosion has for a long time been a major ecological problem in Bayelsa State as in most parts of the Niger Delta. The scale of the problem and the magnitude of land lost due to bank erosion are exacerbated by the dense network of rivers and creeks in the area. The Nun River which runs through Okoloba and Sabagreia among other communities in Kolokuma/Opokuma exercises considerable influence on the hydrology and geomorphological characteristics of the area. Landslides, riverbank collapse and erosion have been common hazards in the area. This study involving the collection of a wide range of data from both primary and secondary sources. The degree of vulnerability and risk posed by flood hazard, recurrent landslides and riverbank collapse and erosion are assessed. The rate and magnitude of riverbank erosion were also determined using, the geographic information system (GIS) integrated with the use of historical satellite imagery of the communities. The results revealed that the average erosion rates for the past 13year period amounted to 1.1538 acre/yr on the left bank and 0.3077 acre/yr. on the right. Riverbank erosion has had adverse effects on cultivable lands, livelihoods and property damage and displaced several inhabitants. Shoreline protection measures, including embankment, the use of revetment of sand-filled permeable polyethylene for safety and enhancement of socioeconomic use of the shoreline is recommended.

KEYWORDS: Flooding, riverbank erosion, Okoloba/Sabagreia, GIS, livelihoods, shore protection measures

INTRODUCTION

One of the most striking features of human settlement patterns is the affinity of man for locations near or by the river. Throughout history, man has been attracted to the lands adjacent to rivers (Fiona, 2009). Today, a very large proportion of the world's population lives in such areas. There are obvious reasons why this would be so. River valleys often contain deposits of rich alluvium and form the basis for the development of thriving agricultural activities. Some of the world's largest civilizations have developed in the lower countries of the major rivers, especially along the banks of the Tigris and Euphrates, the Nile, the Indus and the Yangtze. River valleys are often transport corridors that provide access to roads and railways (Agusomu, 2012).

Flood is defined as a situation where the discharge of a river cannot be absorbed within the margins of its regular channel, so that the water is spread over neighboring land, on crops or forests that can thrive. But sometimes these lands are occupied with houses, factories or transport corridors (Strahler and Strahler, 2013). Flooding and erosion are the most common of environmental hazards. It regularly claims over 20,000 lives annually and adversely affect around 75 million people worldwide (Smith, 2011). The reason lies in the wide geographical distribution of river floodplains and low coasts, along with their longstanding attraction for human settlements.

In the Niger Delta, floodplains and maritime shoreline are used for human settlement and for economic development. These ecosystems are home to over 70 percent of the population, oil and gas installations but at the same time threatened by the natural hazards of flooding and erosion. The scourge of flooding and erosion problems are exacerbated due to human settlements situated at the concave banks which are also the active zones of erosion processes (Ologhadien, 2019).

The fears over the adverse impacts of flooding and river bank erosion on the socio-economic development of the region has dominated political discourse for many years now. Government's commitment to flood and erosion control in the Niger Delta dates back to 1954 and 1961, when the Federal Government of Nigeria commissioned the NEDECO studies. These studies gave a brief description of the Niger Delta, the river systems, and suggested the selection of different flood and erosion protection options and navigation. Furthermore, the creation of the Niger Delta Development Board (NDDB) in 1966 identified the Niger Delta as a "Special Area" which deserves special consideration. Its major terms of reference were to submit schemes designed to promote the physical

development of the Niger Delta together with cost estimates for implementation of such schemes. The NDDB was primarily an investigational body without executive powers to implement the designed schemes.

In 1981, the Federal Government of Nigeria, through the Niger Delta Basin Development Authority (NDBDA), commissioned further studies of the Niger Delta with special emphasis on Flood and Erosion Control and Improvement of Inland Waterways. This report provided detailed bathymetric and hydrographic data of the Nun and Forcados River systems, sediment transport in rivers and longshore transport along the coast. The report presented plausible options to address the flood and erosion problems, and earmarked several prototype schemes for erosion and flood control, land reclamation and waterways improvement. Further, the Federal Government, through the Niger Delta Basin Development Authority also commissioned the Democratic People's Republic (DPR) of Korea to investigate possible flood protection measures in the Nun and Forcados River Area. The Report focused on provision of hydro metrological data for the designs of flood controls schemes, economic development of the Basin and general improvement in the living standard of the people. The Report recommended detailed physical data acquisition towards the development of a master plan. In 1981, the Rivers State Government commissioned Zinkcon International B.V. (Dutch) Company to undertake the design and construction of Flooding and Erosion Protection works for 16 towns and villages. The contract engagement commenced with the construction of two flooding and erosion prototype schemes at Otuokpoti and Sagbama towns. Sagbama town is situated on the left bank of Forcardos River, while Otuokpoti is situated also on the left bank of Ekole creek, a distributary of Nun River.

According to Ologhadien (2019), the prototype schemes were the construction of composite revetment profix materials system which offered combined advantages of reduced hydraulic loading and green solution for river bank protection. The remaining fourteen schemes were abandoned due to change of government and lack of political will to continue with the implementation. The development of flood and erosion problems in the Niger Delta gained impetus with the creation of Niger Delta Development Commission (NDDC). So far, no fewer than 100 shore protection schemes had been sanctioned with no single success and this problem has become a menace to communities located along riverbanks across the Niger Delta Region.

Perennial flooding leading to riverbank erosion has for a long time been a major ecological problem in Bayelsa State as in most parts of the Niger Delta. The Nun River which runs through Okoloba and Sabagreia among other communities in Kolokuma/Opokuma exercises considerable influence on the hydrology and geomorphological characteristics of the area. Landslides, riverbank collapse and erosion have been common hazards in the area and this has resulted to loss of cultivable land, property loss and displacement of people. All efforts made by the Government has so far not yielded any success. It is against the backdrop of these failures that, this study is undertaken. The objectives of the study are to:

1. determine the degree of vulnerability and risk posed by flood hazard, recurrent landslides and riverbank collapse and erosion in the Okoloba and Sabagreia communities;
2. determine the rate and magnitude of riverbank erosion using, the geographic information systems (GIS), integrated with the use of historical satellite imagery of the communities from 2005 to 2018; and
3. to proffer solution to the menace of flooding and associated riverbank erosion in the study area.

RESEARCH METHODOLOGY

The Study Area

Okoloba community is geographically located on Latitude 5^0 03'14"and 5^0 0'47" North and longitude $6^0$12'23" to 6^0 15' 07" East. Sabagreia community, closely located to Okoloba is on latitude 5^0 02'05" and 5^0 03'14" North and longitudinal 6^0 15'07" and $6^0$14'30" to East respectively (Fig. 1). Okoloba is located on the concave part of the bank of the Nun River while Sabagreia occupies the convex part. The study area has high relative humidity and high Mean Annual Rainfall (MAR) amount of about 3000mm and a mixed vegetation type dominated by forest tree (Eli and Agusomu 2018).

The study area is drained mainly by the River Nun running North - South (a first order stream of the Niger Delta, sharing equal status with River Forcados) with a few in-lets and some surface run –offs during rainfall drain into the Nun River at Okoloba reach. Socio- economic activities in the area is dominated by agriculture; including mixed cropping, fishing, trading, transportation, local craft and apprenticeship activities. Both communities had a total population of slightly over 10,000 persons in 1991, projected to some 12,000 in 1996 (NPC, 1991). Projected forward using the exponential growth model, the study communities are estimated to have grown to over 15,000

in 2006 and 20,000 by the study time (2018). The population size of Sabagreia is more than three times more and also bigger in size than the Okoloba community.

Data and sources

The study utilised both the quantitative and qualitative data collection method. Soil samples were collected for the test of soil porosity and flow velocity measurement was also carried to determine the degree of vulnerability of communities to flooding and riverbank erosion. The soil auger was used for the collection of soil samples at pre-determined depths of 0-100 cm along the banks of the Nun River at the study communities during low flood period for easy accessibility. Water flow velocity was measured in the field in a downstream direction using current meters. The rate and magnitude of riverbank erosion were measured utilizing satellite imagery sourced from Google Earth Pro 2018.

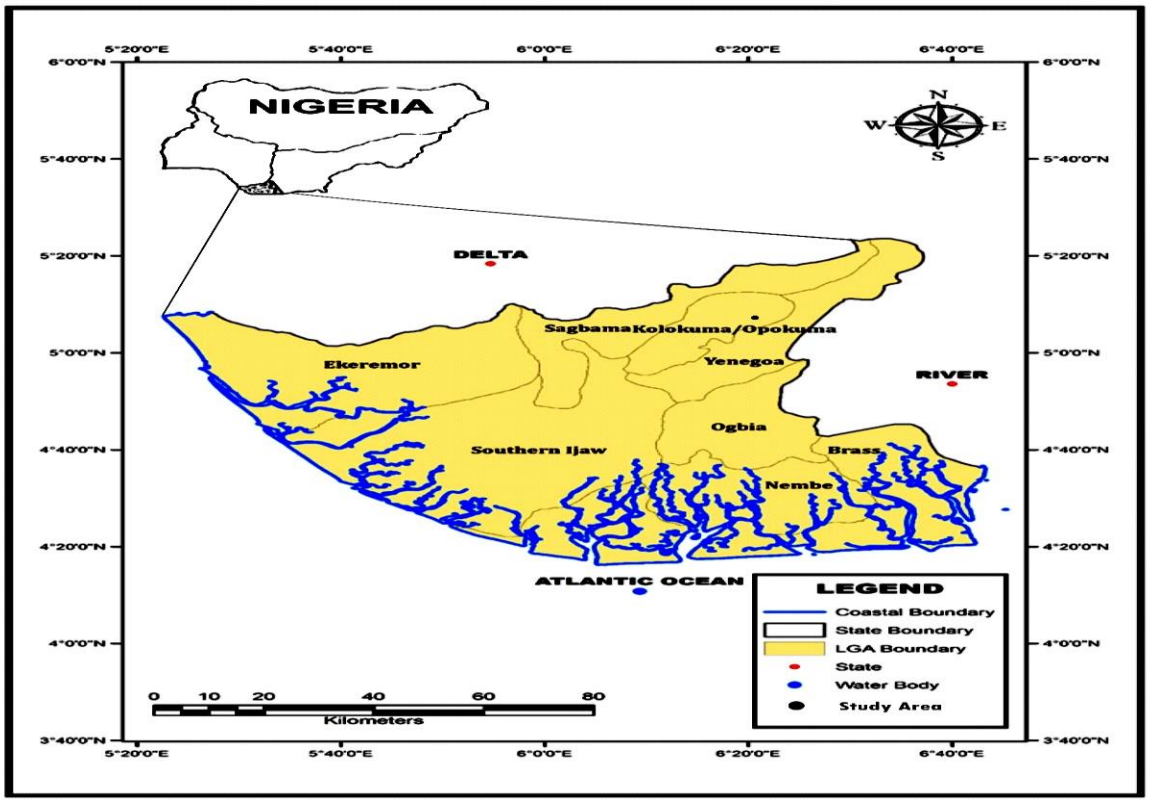

Figure 1: The study area
Source: Adopted from Eli and Agusomu

The questionnaire instrument was also used to obtain information on risk posed by flood hazard and riverbank erosion in the study communities of Sabagreia and Okoloba. Applying the Taro Yamane (1967) formula, some 392 respondents were sampled with the sampled population proportionately drawn from the Okoloba (94) and Sabagreia (298) study communities respectively based on the projected population. The simple random and systematic sampling technique were used to select the respondents from the constituent quarters and streets in the two communities. Participation in the study was limited to family heads and those whose length of residence in the communities was five years and above. This ensured reliability of information from the field, and particularly respondents who must have experienced one severe flooding and riverbank erosion in their communities.

Data analysis and presentation included tabulation, frequency counts and percentages for characterization of socio-demographics. Collected soil samples were analysed in an approved laboratory to determine the soils' porosity since it's the most powerful parameter in terms of the subject matter while the velocity measurement reading was presented in table and discussed.

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To calculate the rate and magnitude of riverbank erosion in the study area, the geographical information system (GIS) ArcGIS 10 was employed. Geometrical calculation gives the amount of eroded area from the year 2005 to 2018. Analyses of sequences of captured imageries provides a means of assessing the extent and rates of riverbank erosion over the past 13 years. The steps in this assessment are:

i. Acquire the historic sequence of captured imagery over the past 15 years in digital format from Google earth pro 2018.
ii. Geo-reference each image and correct for any distortion using 20 control points.
iii. Map the riverbank for each year for which images by tracing the channel/extent
iv. Transfer the mapped riverbank to Geographic Information Systems (GIS) software ArcGIS 10, overlay each of the imagery and determine for each year for which captured imagery of the study area to get the area extent of riverbank erosion

RESULTS AND DISCUSSION

Socio-demographic characteristics

Table 1: Summary Demographics

	OKOLABA		SABAGREIA	
	Frequency	(%)	Frequency	(%)
Administered questionnaire				
Returned	90	95.7	250	83.9
Unreturned	4	4.3	48	16.1
Total	**94**	**100**	**298**	**100**
Sex				
Male	58	64.4	199	79.6
Female	32	35.6	51	20.4
Total	**90**	**100**	**250**	**100**
Age				
Less than 20 years.	2	2.2		
20 - 29 years	18	20	48	19.2
30 - 39 years	33	36.7	77	30.8
40 – 49 years	13	14.4	87	34.8
50 – 59 years	17	18.9	28	11.2
60 – 69 years	5	5.6	8	3.2
70 years and above	2	2.2	2	0.8
Total	**90**	**100**	**250**	**100**
Marital status				
Single	22	24.4	33	13.2
Married	61	67.8	211	84.4
Divorced	1	1.1	-	
Separated	3	3.3	1	0.4
Widowed	3	3.3	5	2
Total	**90**	**100**	**250**	**100**
Household sizes				
1 -3 Persons	25	27.8	23	9.2
4 -6 Persons	47	52.2	183	73.2
7 Persons and above	18	20	44	17.6
Total	**90**	**100**	**250**	**100**
Occupation				
Farming	28	31.1	88	35.2
Fishing	13	14.4	37	14.8
Technician/Artisan	12	13.3	16	6.4
Trading	17	18.9	58	23.2
Business/Contractor	2	2.2	-	
Civil servant	12	13.3	39	15.6

Industrial work	-			
Student/Apprentice/Retired	6	6.7	12	4.8
Others	-			
Total	**90**	**100**	**250**	**100**
Income				
Less than #20,000	43	47.8	138	55.2
20,000 – 29,999	11	12.2	18	7.2
30,000 – 39,999	6	6.7	28	11.2
40,000 – 49,999	12	13.3	30	12
Above #50,000	18	20	36	14.4
Total	**90**	**100**	**250**	**100**

Distance of river to nearest residential dwelling

Our field findings revealed majority of the respondents (>90% in Okoloba and 65.2% in Sabagreia) live within 200 metres from the River Nun as showed in table 2 below. Only at Sabagreia are significant proportions of the respondents found living within 200 and 500metres from the river (34.8%). This obviously indicate many are indeed vulnerable to the ravages or hazards of flooding and riverbank erosion when these phenomena do occur.

Table 2: Distance of residence/dwelling place to the river

	OKOLOBA		SABAGREIA	
Distance of dwelling to River	**Frequency**	**(%)**	**Frequency**	**(%)**
Less than 100metres	10	11.1	23	9.2
100 to 200metres	74	82.2	140	56
200 to 500metres	6	6.67	87	34.8
Total	**90**	**100**	**250**	**100**

Type of houses

Majority of houses lived in by the respondents in Okoloba (70%) and Sabagreai (72%) are constructed of mud wall with zinc roofing, i.e., the wattle and daub type (Table 3). Some 10 percent and 22 percent of the respondents were also found to live in block houses with zinc roofing in Okoloba and Sabagreia respectively. Another group of 18 and 13 of the respondents, representing 20 and 5.2 per cent live in wood-constructed and zinc houses in the study communities respectively as shown in the table.

Table 3: Type of houses

Type of house	**OKOLOBA**		**SABAGREIA**	
	Frequency	**(%)**	**Frequency**	**(%)**
Mud with zinc	63	70	180	72
Block with zinc	9	10	55	22
Mud with thatch	-		2	0.8
Wood with zinc	18	20	13	5.2
Total	**90**	**100**	**250**	**100**

DISCUSSION OF FINDINGS

Causes and degree of vulnerability to flood and riverbank erosion hazard

Both Okoloba and Sabagreia communities are facing fluvial erosion and mass failure along the course of the Nun River. As the raining season starts, abundant rainfall comes about in the area which loosen the soil structure. Soil sample collected from sixteen different sites along the banks and across the banks and analysed revealed they are more of sandy, little clay-sand silt which are unconsolidated across and along the entire reach of the river. Abam, Uko, Ngerebara and Youdeowei (2014), have also described the surface deposits in the area as comprising of silty and sandy- clays. The sandy layers underlying the silty-sandy clay are predominantly medium to coarse in grain sizes and exist in mostly medium state of compaction and underlying the silty top layer is a monotonous sandy layer that is predominantly medium dense to dense in consistency, mostly medium to coarse and even gravelly in some sections. This type of bank material has a great cohesive power, but very little cohesive power when saturated. The materials are exposed to weathering and evaporation during the dry season, get contracted and cracked to a considerable extent. However, during the wet season, the bank material gets saturated with rain water,

penetrating through the crack, resulting to loss of cohesive power, and the bank becomes vulnerable to erosion. When the river stage is high, that is, during flooding, these banks are kept in balance, supported by water pressure of the river. As the river stages get lower after the floods, the bank materials lose their balance and collapse into the river due to osmotic pressure and thus make the communities more vulnerable. Interestingy, the findings here are in conformity with those of Eli and Agusomu (2018).

The average flow velocity has been recognized as the most significant variable affecting channel erosion (Charlton, 1982 and Simon and Li, 1982, as cited in Abam, 2003). This is followed by the high rate of lowering of flood water. The Nun River at the Okoloba and Sabagreia axes experiences high velocity, which increases during periods of flooding, and then worsens the occurrence of bank erosion. The river velocity measurements were taken at sixteen different points, with five (5) different readings taken between the periods of March, 2018 to March 2019. The results on average show that the velocity of the river is very high and decreases downstream; the fastest is at the Okoloba reach and on average runs at a speed of 1.92m/s. The slowest velocity was recorded at Sabagreia reach with an average speed of 1.86 m/s. The findings are in agreement with those of Eli and Agusomu (2018). Remarkably, the velocity is higher at the Okoloba reach, leading to continuous riverbank erosion. Abam (2003) has reported average flow velocity ranging from 0.0 to 2.3 m/sec in the Niger Delta with the highest flow velocity attained in the months of September through to October period, especially at high water stage and along river bends. Riverbank stabilization structures provided at the entrance of Okoloba community were designed to address only fluvial erosion, and thus failed on banks where mass wasting occurs. Riverbank infrastructure limits the geomorphic processes that transfer sediment through dynamic natural systems and this lead to undesirable secondary effects. According to Joan, Mount and Chin (2008), such structures can shift the locus of erosion as the river adjusts to the hardened area that the structure presents and these structures can narrow channel width, leading to higher flow strength and thus initiating a cycle in which the increased flow strength (high velocity) in combination with reduced sediment supply, leads to channel deepening. The deepening may in turn increase bank height and accelerate riverbank erosion.

It was also discovered that the gradient is the sharp-steeped type at Okoloba. At most points, it is as sharp as 90 degrees (i.e. at right angle). Because the banks are steep, with high failure rate, vegetation is hardly sustained on the bank face. However close to the crest of banks, the trees which have large biomass frequently act as surcharge and readily induce bank failure, which contrasts with the slopes at the Sabagreia axis which are relatively gentler.

Rate and magnitude of erosion

It has been identified that the highest erosion period was from 2010 to 2015 and the area extent of erosion was found to be 3.6098 and 0.8041 hectares of land across and along these communities respectively as shown in figure 2 below. Within this period, Nigeria witnessed high amount of flooding, particularly in 2012 (NEMA, 2014). The area extent of river bank erosion between the years 2005 to 2010 was calculated to amount to a total area extent of 1.6187 hectares of land with the rate of riverbank erosion in 2015 to 2018 (Figures 3 and 4).

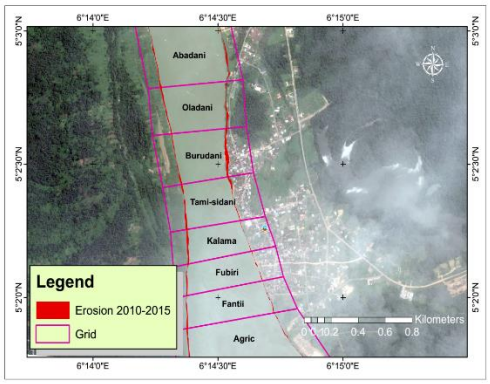

Figure 2: The rate of riverbank erosion from 2010 to 2015 in Okoloba and Sabagreia

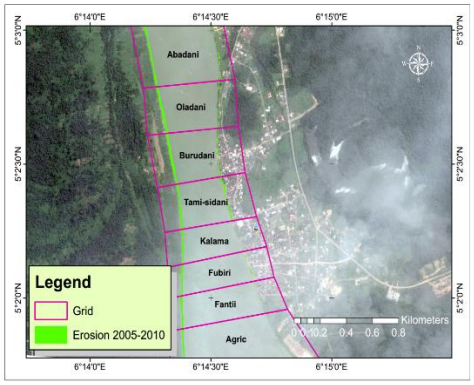

Figure 3: Rate of riverbank erosion between 2005 and 2010 in Okoloba and Sabagreia

Source: Authors' Fieldwork (2019)

Of the 3.1km length across the study communities, riverbank erosion took place along its entire reach during the 13 years' period, i.e., 2005-2018. The highest eroded area was observed at Oladani axis of Okoloba community

with the total eroded extent of 0.9874 hectares in the period of 2005 to 2018. The total eroded area across these communities riverbank is 6.0703 hectares; 3.8364 and 2.2339 hectares of land eroded at Okoloba and Sabagreia respectively. The total changes of Nun River at Okoloba and Sabagreia riverbank is shown in Figure 5 below.

It is pertinent to note that the highest amount of riverbank erosion along the Okoloba and Sabagreia communities from 2005 to 2018 was found to be very high with an area extent of 0.7365 and 0.4977 hectares of land at the Burudani and Oladani axes of Okolona community. The highest rate of erosion on the along banks of Okoloba and Sabagreia were found to be 0.0567 and 0.0364 hectares of land per year in Burudani and Oladani respectively.

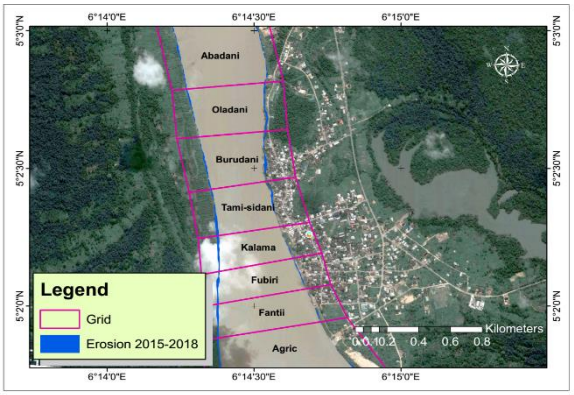

Figure 4: Rate of riverbank erosion between 2015 and 2018 in Okoloba and Sabagreia
Source: Authors' Fieldwork (2019)

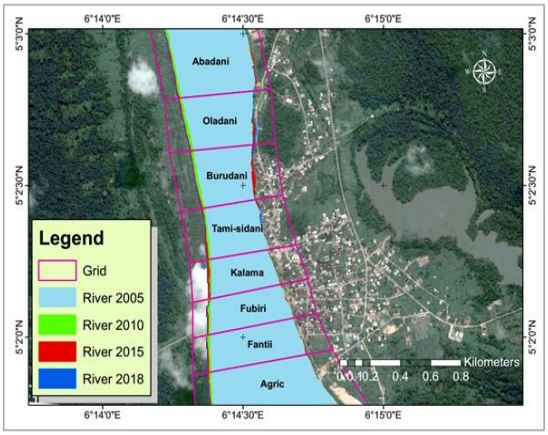

Figure 5: Riverbank erosion between 2005 and 2018 in Okoloba and Sabagreia
Source: Authors' Fieldwork (2019)

Risk posed by flood hazard and riverbank erosion

Flooding and riverbank erosion have enormous impacts on life and property at the Okoloba and Sabagreia study communities. The livelihood system in the study area is mostly dependent on agriculture and related activities. Okoloba community have experienced severe riverbank erosion. The actual statistics of infrastructural losses are not available at the local government office or the state office database because of lack of proper monitoring systems. But information provided by the local people suggested infrastructural losses have placed huge stress on the local economy, education, culture, social development and strategic impact on the inhabitants of the study area. Specifically, the major losses have been on houses, road, embankment, jetty, graveyard and many others located close to the riverbanks.

The stronger the housing structure, the lesser the vulnerability to flooding and erosion hazard. But out of experience and poverty, people in the study area construct their houses more with ephemeral building materials for easier relocation within short periods during such flooding bank erosion disasters. Such provision makes them less vulnerable in managing the cost of housing. As the study revealed, more than two-thirds of the respondents (70% and 72%) in Okoloba and Sabagreia respectively have their houses constructed of mud wall and zinc roofing. As Uddin and Rahman (2011) noted elsewhere, housing structure determines the susceptibility to flooding and riverbank erosion. Between the study period (2005 to 2018), over thirty fiver (35) houses in Okoloba were reportedly eroded away including the only jetty built for riverine transportation and thus, hindering the economic progress of the community. Many houses have also been abandoned for fear of riverbank collapse and erosion. It was also observed that though the magnitude of riverbank erosion is higher at the Burudani axis of the Okoloba community, property loss was more at the Oladani axis of the community. This is because of the location and proximity of houses at the latter than the former. Also, location of houses was farther from the river at Sabagreia community. The study findings agree with those of Dey (2006) in Queensland, where he found that most rivers erode their banks massively especially at the reaches where settlements and human activities are associated by accelerating influences from both physical and human factors.

Soil fertility of the eroded area was also found to show a tremendous change. Due to siltation, the top soil layer in the agricultural fields are overlain by a thin sheet of fine sands which are less fertile. By losing the top soil, the potential agriculture lands become barren and therefore the crop production has a very low yield.

CONCLUSION AND RECOMMENDATIONS

The people of Okoloba and Sabagreia have been experiencing river flooding and riverbank erosion in last few decades. Huge amount of fertile agricultural land is eroded every year. Many families of the area who were totally dependent on agriculture had lost their farmlands, and associated agricultural produce, and residential houses among others which have made them socio-economically vulnerable. Some families too, having lost dwellings have been displaced. The riverbank protection structures at Okoloba and Sabagreia communities have failed due to absence of drainages, pour water pressure development behind the geotextiles and gabion mattresses which then generated land sliding and slope failures. Based on the study findings, the following are recommended:

1. People living within 200 meters away from the riverbank in the Okoloba and Sabagreia communities are advised to move further inland, as more severe catastrophic events of riverbank erosion are expected to occur as the Nun River adjusts continuously.
2. Concerted efforts should be made by Government to construct more durable and sustainable shoreline protection measures, including embankments, the use of revetments of sand-filled permeable polyethylene for safety and enhancement of socioeconomic use of the shoreline.
3. Engineers charged with designing riverbank protection structures should pay special attention to flood frequency and slope stability analyses.
4. Finally, consultants with core competence in River hydraulics engineering and geotechnics should be engaged for the design of shore protection works.

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