Utilizing Google Earth Pro Image in Mapping River Bank Erosion along Ekole creek in Ayama Ogbia Community, Bayelsa State, Nigeria

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***Abstract*: This study is aimed at mapping the extent of riverbank erosion utilizing historical Google Earth Pro images. The study area is located along the Ekole creek in Ayama Ogbia Community. The study focused between the period 1985 to 2021. To determine the extent of erosion, Google Earth Pro Satellite images of 1985, 2003 and 2021 were respectively utilized. The results reveal that river bank erosion extent occurs at transect line L1 to L8 along the river bank. The study further revealed that erosion is more highly impacted at transect line L4, L5 and L6. Given the findings of the study, it indicates that the locations where erosion has impacted the river bank of Ayama Ogbia Community are predominant caused by forces of both natural and human activities occur in the area. The study recommends amongst others, that government should intervene in these areas affected by erosion simply by embarking on erosion control measures.**

***Keywords*: Google Earth Pro Images, River Bank Erosion.**

1. Introduction

River banks serve as site where most communities settle and often times, they are high enough to enable such communities escape river floods and importantly they also serve as ground for cultivation. River bank erosion has been identified as one of the major environmental problems affecting the Niger Delta of Nigeria. The Niger Delta region, constitute one of the world's biggest wetlands comprising over 20,000km2 in southern Nigeria (World Bank, 1995). The river Niger which is acclaimed to have the ninth largest drainage area of the world rivers is said to constitute a vast interface between land and water systems.

More so, the delta is ecologically very complex due to the vast link between land and water systems. Rainy season is accompanied by high rainfall and river discharge, which when linked up with the low, flat terrain and badly drained soils, cause widespread, riverbank erosion which constantly cause devastating effects leading to crop loss, livelihood loss and destruction of houses. Ayama Ogbia community in Bayelsa Sate which forms part of the Niger Delta is one of the communities highly affected by riverbank erosion. River bank erosion occurs frequently in Ayama Ogbia Community, with increasing intensity as the years go by. The occurrence comes with other associated problems in the community. Moreover, despite the intensity of the situation, none of the federal and state MDA'S (ministries, departments and agencies) have actually addressed the problem and no management plans have been developed. Given the fact that river bank plays an important role on the development of the socio – economic lives of the inhabitants of Ayama Ogbia community, its continuous loss portends a great danger to the ecological, social and economic stability of the community. At the global level, many researchers have attributed the problem of river bank erosion to a myriad of interrelated problems (Razzak and Sultana, 2020; Hossain, Abam, and Haque, 2020; Aloni and Alexander, 2021).

In the context of Bayelsa State, Nigeria, studies have tried to put emphasis in providing broader knowledge on the fundamental factors which contribute to river bank erosion, and improvement in bank protection design (Abam, 1993; Egirani, 2002; Ejezie and Will, 2017; Eli and Agusomu, 2018; Ologhadien, 2019; Aseyaifiti, 2020). Characteristic of these earlier studies is the lack of focus on empirical quantification of spatio temporal changes. Therefore, the need for continuous empirical research and analysis in the area is imperative.

However, study carried out by Khan et al (2022) and Rahman, Islam, Salman and Rafia (2022), outside Nigeria, utilized historical data capacity of Earth Pro Images to analyze the spatio temporal changes taking place on river banks as a result of erosion. Findings from both studies showed areas that are vulnerable to river bank erosion. On the basis of the foregoing, this research undertook adequate empirical studies and analysis through the utilization of historical data extension of Google Earth Pro images, to map spatio temporal changes and quantify changes that have occurred along the Ayama Ogbia Community section of the Ekole creek. It will also be used to indicate the sections vulnerable to erosion. This will fill the gap of lacking empirical research analysis in the area.

This study seeks to identify areas vulnerable to river bank erosion and to estimate the rates of erosion in these areas, to recommend appropriate measures for the management of these areas along the river bank. This study further reinforces the need for the utilization of historical images to access years of changes in landscapes over time, and to identify possible opportunities to monitoring or mapping damages from natural disasters and enhance sustainable management of riverbanks. Hence, this research has important links with current international and national policy initiatives that are aimed at improving water resources. It thus, cuts across multiple Sustainable Development Goals (SDGs).

A. Study Area

The study area is Ayama Ogbia situated along Ekole creek in Ogbia Local Government Area of Bayelsa State (Fig 1.) Ayama Ogbia is geographically located within latitude 4º 44' 42' N and latitude 4º 46' 12"N and between longitude 6º 13' 30"E and 6º 14' 42"E. It is a meandering creek; the local socioeconomic, as well as the transportation system predominantly depends on it (Egirani, 2002). In the Ayama Ogbia section of the creek, houses as well as farmlands are located at the bank of the creek (Egirani, 2002).

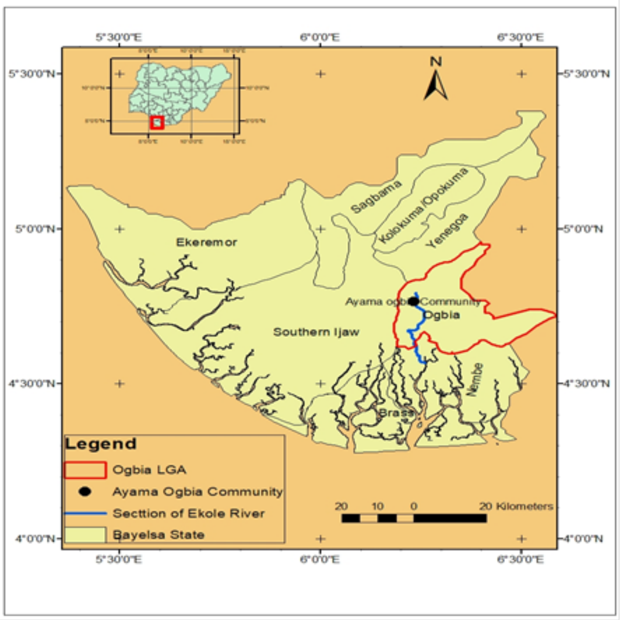

Fig. 1. bayelsa state map showing local government areas, ogbia LGA and section of ekole creek

2. Conceptual Framework

A. Concept of Google Earth Pro

Google Earth Pro is a without charge online software that permits visualization, assessment, overlay, and creation of geospatial data even though it is not a true GIS (University of Ottawa, 2021). Google Earth Pro is one of the available versions of Google Earth, which until January 2015 used to rely on monetery subscription (Keyhole Incorporations, 2020). It is an improvement on the Google Earth version that provides customers with the following features; GPS integration which permit users to read tracks and waypoints from a GPS device, view historical imagery, navigate to a city with the direction's module, import shapefiles, geocode address and create a route (Keyhole Incorporations, 2020). In addition to the foregoing, compared to its Google Earth version, Google Earth Pro provides additional useful features such as import GIS data from ESRI shp; MapInfo.tab; import large image files through image overlays; supplemental layers such as Demographics, Parcels, Traffic Counts; and measurement tools such as Line, Path, Polygon, Circle, 3D Path, 3D Polygon (Keyhole Incorporation, 2020).

Google Earth's Pro historical imagery feature enables users to access years of satellite, aerial and street view imagery which are an effective tool to demonstrating the development of cities, monitoring or mapping damages from natural disasters and changes in landscapes over time (Ngucha, 2015). Due to the nature of interactive display of geographic information in the form of a web page, Google Earth Pro images are categorized as web maps. A web map is defined as an interactive display of geographic information in the form of a web page that can be used to tell stories and answer questions (Dorman, 2021). The term interactive implies that the user can interact with the map by selecting different map data layers on features to view, zooming into a particular part of the map that the viewer is interested in, inspecting feature properties, editing existing content or submitting new content etc (Dorman, 2021). Google maps are categorized as web maps for the purposes of computational tools (Dorman, 2021). However, due to its capability of enabling the user view historical images, Google Earth Pro has advantage over other web-based applications. This function gives Google Earth Pro the capacity to map changes occurring in a specific geographic area in order to anticipate future conditions, decide on a course of action, or to examine the results of an action or policy (University of Wisconsin-Madison, 2022). The capability of Google Earth Pro for mapping has been extensively used by various researchers for variety of purposes.

The levels of accuracy of maps produced from Google Earth and other sources are very important to the map user. Surveyors Council of Nigeria (SURCON) (2007) defined accuracy as the degree of perfection attained in the determination of quality. In the establishment of horizontal control networks, it is convenient and sufficient to define the minimum accuracy of a line as the ratio of the standard error of that line (after an appropriate least squares adjustment) to the length of the line. Thus, if the length of the line is 1, and the standard error is S then, denoting the accuracy by 1/p, we write 1/p = s/1 ---------------------- equation 1

For each line of the network, there is one value for P in equation (1). By adopting a system of accuracy classification for all control points, we take a range of values from equation (1) as belonging to one order to work. For this purpose, the highest value of P in each range will not lie below the value adopted for the order. This is the basis for the classification of all horizontal control points in the country (SURCON, 2007).

Going by the National Horizontal Control Accuracy Standard (SURCON, 2007), Google earth maps are categorized under Class 1 Third-Order surveys where the principle used include, control for urban mapping and cadastral control densification. The accuracy is stated as 1:10,000 (100ppm). However, the positional accuracy for Google Earth has been evaluated by many authors and it has been found to fit the production of class – 1 map and having accuracy above the specified 1:10,000 (Bonugli and Frend, 2015; Muhu and Dereb, 2019; Gui et al, 2020).

B. Concept of Mapping

A map is a two-dimensional scale model of a part of the surface of the earth (Fabiyi, 2001). This model is a systematic description or representation of the part of the earth, generally using symbols to represent certain objects and phenomena (Fabiyi, 2001). Maps are effective ways of presenting a great deal of information about objects and the spatial relationship of objects. Maps can also be defined based on the conventional concern of cartography, which is to reduce the characteristics of large area – a portion or all – part of the earth or another celestial body and putting it in a map form to make it observable (Robinson et al, 1995). Maps can also serve as a medium for communicating information about the surface of the earth to its users. This important aspect of cartography is greatly influenced by modern technological development such as digital technology (any Google Earth Pro, Digital theodolite, GPS etc) and Geographic Information Systems (GIS). In this context, a map can be described as an image that serve as the medium of communicating and conveying spatial relationships to its viewer. Mapping is the process of making model that are accurate abstraction of the earth and phenomena on and near its surface, but generalized to two dimensions (flat). Accurate mapping requires precise measurements of the Earth’s size and shape. The size and shape (called a geodetic datum) established the reference frame unto which themes, topics and features can be displayed.

Various types of maps can be classified using different approaches. For example, map can be broadly classified based on the method of compilation, therefore, we have digital/basic mapping and derived mapping. In the context of basic mapping, it can be described as the process of compiling maps from the basic data such as survey booking, GPS readings among others, using images as a base for mapping, etc. Derived mapping are all production of maps that are produced by improving on quality or the color rendition of the former (Fabiyi, 2001). Sometimes these are classified as quantitative mapping and qualitative mapping respectively. These describes the process of making these different maps. Others have classified maps based on their contents, therefore, there are planimetric maps and topographic maps, chloroplets maps etc (Olomo, 2008).

Apart from its traditional function of representing an abstraction of a selected part of reality, maps can be a fundamental part of a search engine, with particular reference to geospatial data infrastructure (Kraak, 2004). They can also act as interface linking geographic and non-geographic information on the Web (Kraak, 2004), and also function as a medium for performing mapping exercise that will detect and monitor changes that are taking place in the environment. For example, the application of Google Earth Pro for mapping is capable of detecting changes that has been taking place in the environment over time.

C. Evaluating the Spatio Temporal Changes of River Banks

Leopold, Wolman, and Miller (1995) defined river bank within the context of limnology (the study of inland waters) as the terrain alongside the bed of a river, creek or stream. In fluvial geomorphology, stream banks are of particular interest due to the studies and processes linked with rivers and streams and the deposits and land forms that evolve from them. Banks are commonly described as either left bank or right. These descriptions are often dependent on the perspective of an observer looking downstream.

River banks are a very crucial part of the life of the river (Young People’s Trust for the Environment, 2021). It provides breeding sites for mammals and birds, habitat for adult insects etc. They also provide areas such as flood plains and maritime shore for human settlement and for economic development. For example, the ecosystem of the Niger Delta region of Nigeria which constitute delta, floodplains, maritime shore and river banks, accommodates well over 70% of its population, oil and gas installations (Ologhadien, 2019). In Malawi, along the river banks in Salima District, Zidana et al (2007) revealed that due to the rich nature of the soil for cultivation, farmers engage in river bank cultivation without conserving the soil. This approach enables farmers to sustainably derive their livelihood from the land without degrading the environment.

Despite the aforementioned recorded importance of river banks to the social and economic existence of humans, this fragile environment nonetheless is still massively affected by natural disaster such as erosion that is wearing away bank materials. It is a dynamic process that affects the concave side of the bank, while depositing sediments on the opposite side (Chatterjee and Mistri, 2013). The impact of river bank erosion on the physical environment, and socio-economic life of people residing on communities situated along river banks is well documented (Baki, 2014; Das et al, 2017; Oyadougha, 2018; Razzak and Sultana, 2020; Hossain, Abam, and Haque, 2020; Aloni and Alexander, 2021).

Various studies have ascribed causes of river bank erosion to many different factors (Girku, Hassan, Yakubu and James, 2017; Eli and Agusomu, 2018; Okeke and Kogure, 2020). Although river bank erosion is a common phenomenon, identification of the location and extent of river bank erosion is different. Therefore, a range of approaches and methods have been developed and tested (Varouchakis et al., 2016; Akter, Tuz Zahra, Sajon and Sen, 2018). Varouchakis et al (2016) stated that the most important issue concerning river bank erosion is the identification of the areas vulnerable to bank erosion as well as to determine changes in river channel and quantify the extent of erosion in order to assist stream management/restoration options. However, riverbank erosion is usually approached by using remotely sensed historical data to identify vulnerable areas and estimate the erosion rate (Bernier, Chassiot, and Lajeunesse, 2021). One of the methods that has an edge over every other method is the utilization of Google Earth Pro mapping software. Unlike commercial mapping softwares, they are free, map location can be displayed with varied icons, allowing a visual ranking or classification system. It also allows sites to be identified in a variety of ways; by pointing to a location on a map, by inputting an individual address from a spread sheet file or database, additional layer availability, historical view, extremely detailed, up-to-date maps and data, and available or a wide array of devices (Lefer, Anderson, and Banquers, 2008).

3. Theoretical Framework

A. System Theory

Systems theory is an interdisciplinary theory that considers nature, society and many scientific domains to be made up of systems and as well as a structure that can probe various phenomena from a holistic perspective (Mele, Pels and Polese, 2010). It is developed by Von Bertalaffy in the 1950's (Von Bertalanffy, 1951; Lai and Lin, 2017). Systems are cohesive groups of interrelated, interdependent components that can be natural or manmade (Wikipedia).

The goal of systems theory is to explain the dynamic interaction and link between components of a system. A system is accepted accordingly in line with the order and form of the relationships emerging from the interplay among components. As a result of these emergent order and form, each system can be distinguished from another. Based on the foregoing, systems are categorized as natural (e.g., river), or built (e.g., political), physical (e.g., transport) or conceptual (e.g., plan), closed (e.g., world hydrologic cycle) or open (e.g., coastal) static (e.g., bridge) or dynamic (e.g., human). Closely related to its elements, a system can be referred to in terms of its components, composed of various parts, processes and products; its attributes, composed of input, process and output characteristics of each component; and its relationship composed of interaction between components and characteristics (Tien and Berg, 2003).

The drainage basin system is one of the several systematical theoretical constructs of the General Systems theory. A drainage basin is referred to as an open system. It is considered as a whole in relation to all its component parts and their attributes (Zavoianu, 1985). At its natural state, basin area is put through continuous flows of matter and energy. The amounts of matter and energy received in the drainage area acts upon the variables defining the characteristics of a basin. Some of these quantities are stored in the basin while others leave the system through different means. Thus, unstored water can transpirate or evaporate or leave as river runoff. The drainage basin system theory is very important to this work as external variations in environmental control such as the case attributed to man's actions causes responses of the system to abnormal processes of erosion and aggradation.

However, the environmental characteristics of the drainage basin impacted by human activities can be determined in order to obtain quantitative information that can be useful for developing environmental management policies of the drainage basin, such as policies on management of soils, lakes, rivers and water resources. One of the means of obtaining such information is by mapping the spatio temporal characteristics of the drainage basin. Ashaolu, Olurunfemi and Fabiyi (2019) evaluated changes in Osun drainage basin in Nigeria by assessing the spatio-temporal pattern of landuse and land cover changes.

4. Research Methodology

A. Research Design

This study adopts the longitudinal survey design. The nature, types and sources of data required for this study include; data on the rate, extent and magnitude of riverbank erosion which includes the measurement of riverbank via satellite imagery of the study area, sourced from Google Earth 1985 and 2003, Google Earth Pro 2021. Data was collected from both primary and secondary sources. The primary sources of data collected involved collection of information from the field through careful observation and measurement. The secondary datasets were sourced from already existing records, which include Google Earth Satellite Images (1985, 2003 and 2021), and textbooks on geo-informatics and fluvial geomorphology, relevant journals and other papers relevant to the study.

B. Methods and Procedures of Data Collection

The method of data collection employed in this research involved historical data collection and observation. The Global Positioning System (GPS) coordinates and Google Earth Images were applied to map and generate an inventory and estimate the rate of change in riverbank erosion in the study area.

C. Data Analysis

The data collected was analyzed using Google Earth Pro web-based mapping application.

To examine the extent of riverbank erosion in Anyama community within the period of 1985-2021, the measure analysis was performed. The measure tool in Google Earth Pro was utilize to quantify the extent of riverbank erosion in the study area. For the analysis of riverbank erosion extent to be determined, an historical database of the riverbank was created in Google Earth images. Each riverbank image of 1985, 2003 and 2021, were digitized and converted to polyline data. The digitizing was carried out based on the water land boundary for each year extracted from the satellite images. The digitized riverbanks were appended on a recent satellite image (Google Earth Pro, 2021) which creates a spatial database of historical shoreline positions.

An onshore baseline was constructed by on-screen digitizing on a grid line of longitude in the Google Earth image. Thereafter transect line were cast perpendicular to the baseline in the direction of the riverbank and over-layed on the historical banks. The transect lines were labeled L1 to L17 and the perpendicular line was labeled A at the top position and B at the lower position (figure 2.0). The extent of erosion was measured along each of these transect lines.

The annual rate of erosion was determined from the formula below based on simple proportion;

$$\text{Annual rate of erosion} = \frac{\textit{extent of erosion under period of study}}{\textit{years of period under study}}$$

------------------ ------ equation 2

Source: Formula generated by the author

5. Results and Discussion

To answer this research, question the relevant data collected for the purpose were analyzed as shown in Table 1 and Figure 2.

Table 1

Spatio-Temporal riverbank changes within the period 1985 to 2021

Line	Year	Rate Of Erosion (M)	Annual Rate Of Change (M)
L1	1985 –	13.37	0.743
L1	2003	9.35	0.519
	2003 –		
	2021		
L2	1985 –	6.73	0.374
L2	2003	14.22	0.790
	2003 –		
	2021		
L3	1985 –	6.18	0.343
L3	2003	12.59	0.700
	2003 –		
	2021		
L4	1985 –	10.81	0.601
L4	2003	27.86	1.548
	2003 –		
	2021		
L5	1985 –	7.63	0.424
L5	2003	29.81	1.656
	2003 –		
	2021		
L6	1985 –	9.81	0.545
L6	2003	31.19	1.732
	2003 –		
	2021		
L7	1985 –	10.84	0.602
L7	2003	24.30	1.35
	2003 –		
	2021		
L8	1985 –	10.65	0.592
L8	2003	16.92	0.940
	2003 –		
	2021		
L9	1985 –	8.14	0.452
L9	2003	9.32	0.518
	2003 –		
	2021		
L10	1985 –	5.77	0.321
L10	2003	8.59	0.477
	2003 –		
	2021		
L11	1985 –	5.13	0.285
L11	2003	0.72	0.040
	2003 –		
	2021		
L12	1985 –	3.14	0.174
L12	2003	4.37	0.243
	2003 –		
	2021		
L13	1985 –	6.32	0.351
L13	2003	10.65	0.592
	2003 –		
	2021		
L14	1985 –	1.10	0.061
L14	2003	3.49	0.194
	2003 –		
	2021		
L15	1985 –	2.37	0.132
L15	2003	1.94	0.108
	2003 –		
	2021		
L16	1985 –	4.11	0.228
L16	2003	6.73	0.374
	2003 –		
	2021		
L17	1985 –	4.85	0.269
L17	2003	9.12	0.507
	2003 –		
	2021		

Source: Author's Fieldwork and analysis of Google earth pro image, 202

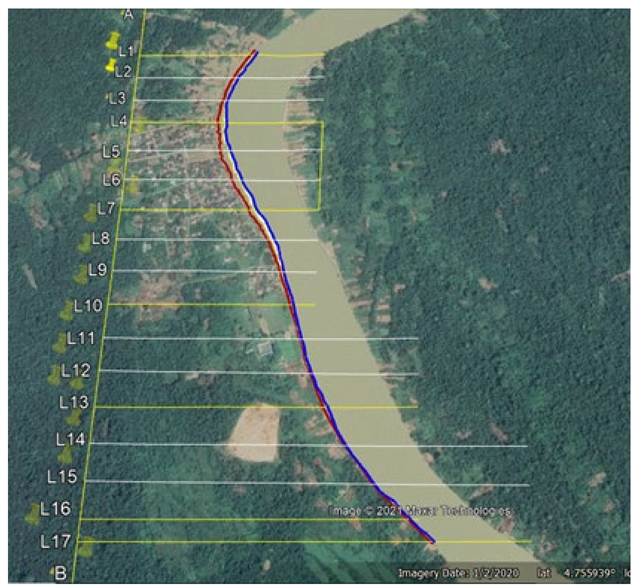

Fig. 2. Transect lines and Spatio-Temporal River bank of 1985, 2003, and 2021 overlayed on google earth pro image of 2021.

Source: Author's fieldwork analysis of google earth pro image, 2021

The data analysis presented in Table 1.0 and Figure 2.0 shows that riverbank erosion has been studied at two difference epoch of 1985 – 2003 and 2003 – 2021. Results from the two epoch of study show that bank erosion is occurring at the two epoch and is most impacted on the bank along transect L1 to L8 which are situated at the concave side of the Ayama river. Eli and Agusomu (2018) found out that river bank erosion is most impacted at the concave side of a river. Their study shows that high stream velocity, sinuous meandering and the development of riffles and pools along the system leads to under cutting which is easy at the concave banks. Also, Bhuiyan, Islam and Azam (2017) suggest that loss of land through river bank erosion is capable of turning wealthy farmers into marginal farmers. Furthermore, loss of land can also lead to loss in infrastructure, properties and migration of people. These situations according to Alam and Haque can lead to prevalence of depression, anxiety and stress (DSAS). However, abuse of substances, smoking, alcohol use as well as stress, sleep disorders have been found to be associated with people suffering from depression anxiety and stress (DSAS). However, the study area is observably losing lands rapidly to river bank erosion. As such, farmlands are been lost, as well as infrastructure and properties.

Also, from Figure 2.0 the study shows that erosion is recorded to be most highly impacted between transect lines L1 to L8 on the concave side of the bank. This area constitutes the most populated area of the Ayama Ogbia community and constitute the densely built-up area. Eli and Agusomu (2018) suggest that most anthropogenic activities such as cropping and building on banks and sand mining along the river bank or close to the river bank are capable of causing river bank erosion. However, the area most impacted by bank erosion along transect line L1 to L8 along the Ayama Ogbia community river bank may be as a result of anthropogenic activities. Observably, this area is densely built-up and many of the anthropogenic activities recorded to be responsible for river bank erosion occur within the transect area of L1 to L8. Also, results from Figure 2.0 and Table 1.0, show that the dynamism of river bank erosion occur more between the study period of 2003 – 2021 than an earlier study period of 1985 – 2003. Analysis of bank erosion by Aditi (2020) suggest that banks erode gradually at different rates at different directions and at different time span. Furthermore, Aditi (2020) suggests that one factor that can be responsible for erosion at different time in space is flooding. The study stated that during flooding, higher velocity of water brings enough energy to tear away the top layers of soil or even cause mass failure. However, the study area has been experiencing high level of flooding since 2012 till 2021. This period however, coincides with part of the study period of 2003 – 2021. These findings may explain the high level of bank erosion occurring within the study period of 2003 – 2021.

6. Conclusion

Based on the findings of the study, the following conclusions were drawn.

1) The study found that there is occurrence of river bank erosion in the study area all through the two phases of study period, 1985 – 2003 and 2003 – 2021. Erosion during this period is attributed to high stream velocity, sinuous meandering and development of riffles and pools along the system.
2) There is a gradual loss of farmland, infrastructure and properties to river bank erosion in the study area and within the study period. This implies that affected residents of the community may be undergoing depression, anxiety and stress that could lead to abuse of substances, sleep disorders, smoking, alcohol use etc.
3) River bank erosion in the area and within the study period is mainly attributed to uncontrolled anthropogenic activities.
4) The high rate of river bank erosion occurrence in the second phase of study between 2003 – 2021 could be linked to massive flooding in the area.

7. Recommendation

Following the findings of the study, these recommendations are presented which may be of use to the Bayelsa State Ministry of Environment, Ministry of Works and Infrastructure, Ayama Ogbia Community, Non-Governmental Organizations, and other professional bodies to adopt;

1. Government should intervene in these areas affected by erosion, by carrying out erosion control measures, otherwise as shown in the study greater part of the land area of Ayama Ogbia community will be eroded into the Ekole creek.
2. Government should sponsor further studies along the Ayama Ogbia riverbank to determine the causes of riverbank erosion.
3. It is necessary to begin an extensive remediation project in Ayama Ogbia community to restore and protect the river bank.
4. Government should embark on a formal professional and comprehensive assessment of river bank erosion in the study area.
5. The inhabitants of Ayama Ogbia community should be enlightened to exhibit the right attitude towards the use of the river bank in their socio-economic activities
6. Town planning measures should be adopted to restore riparian buffers or protect riparian vegetation that stabilize the bank and also to control other activities that may cause bank erosion.
7. The government should embark on river training as a long-time regional approach to mitigate river bank erosion in revetment, and sheet piles may be applied cautiously.

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