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Understanding the Drivers of Persistent Flooding in Bayelsa State Using Space Science and Technology

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Abstract

The world's worst natural disaster, flooding has frequently had a severe impact on how human communities are structured along sociocultural lines. Floods in Nigeria are said to affect and uproot more people than any other calamity. It also results in greater property damage. People, communities, and institutions are at risk when there is a flood disaster. Recently, floods in Nigeria, particularly in the Niger Delta region, forced the majority of the population to leave behind their sociocultural and economic roots. The situation in Bayelsa State was the most appalling, although the State was one of the worst affected within the Niger Delta. The study looked at the sociocultural consequences of floods in Bayelsa State. To achieve this, data was acquired from two years 2013 and 2022 respectively from Landsat8 imagery. It was shown that settlement within the flooded area was 4% and 2%, flooded vegetation was 13% and 18% flooded farmlands were 2% and 8% respectively. Raising to low farm products and displacement of properties. The government can use this technic to arrest the issue of food security in the state and in the country at large.

1. **0 Introduction**

Of all the different sorts and magnitudes of environmental risks, flooding is one of the most catastrophic, common, and pervasive (Zurich, 2022). All rivers and natural drainage systems occasionally experience flooding, which is an unavoidable natural occurrence that harms people, the environment, and natural resources as well as causes yearly losses in the economy and health (Odufuwa, et. al., 2012). A tremendous amount of water covering a dry area is what is known as a flood. It happens when water briefly fills a space where it normally does not because of excessive rainfall and the discharge of more damage than the soil and plants can hold. More water rushes off the land than can be contained by rivers, streams, ponds, and wetlands. Such natural heavy rains may lead rivers to overrun their banks and spill onto the neighboring floodplains. Floods are a natural occurrence that depends on the geography of the area, prior moisture conditions, and rainfall totals in addition to other factors. It has caused property destruction, human displacement, and death (World Health Organization, 2020). Fluvial (riverine), pluvial (ponding), flash, coastal, and urban floods are the five main types of flooding that can occur (Puroclean, 2020). Fluvial floods happen from river water when the banks of rivers overflow, typically as a consequence of severe rainfall. Pluvial floods, on the other hand, happen when there is an abundance of rain, to the point that the natural drainage systems are saturated and unable to release water. Flash floods happen when water levels increase quickly to hazardous levels without much forewarning (Pittsburgh, 2022). Usually, it happens when there has been a lot of rain in a very small region. Metropolitan floods are caused by land development that lacks adequate drainage, usually in urban areas. A strong storm (storm surge), a high tide, a tsunami, or a combination of them all may cause the sea to overrun or topple flood defenses like sea walls. Due to its position in the Niger Delta, Bayelsa State is considered to be one of Nigeria's states that is most vulnerable to floods (Obinna, et. al., 2014). Even before there was widespread knowledge of climate change, floods caused by yearly coastal rising waters plagued the majority of the state's villages and the Niger Delta. Recent flood catastrophes in Bayelsa State and throughout Nigeria have destroyed a great number of homes and lives while also posing a danger to natural biodiversity. Climate change causes floods in the State every year, which cause catastrophic losses in terms of lives lost, financial assets lost, and school attendance, with further ramifications for the educational system (Berezi et. al., 2019). Bayelsa state had severe effects from the floods in 2012 and 2022, which were caused by the pandemic climate change and the release of Lake Lagdo, respectively. Schools were forced to close as a result.

The humanitarian ministry asserts that flooding in 2022 was comparable to Nigeria's most recent significant floods in 2012, which resulted in 363 fatalities and 600,000 displaced persons (Nimi & Aliza, 2022). Marine environments basically refer to sea or oceanic environments, while the coastal environment is the interface between the land and sea, which is comprised of a continuum of coastal land, aquatic systems, as well as the network of rivers and estuaries, islands, transitional and intertidal areas, wetlands, and beaches. Coastal environments are arguably the most complex and vulnerable environments on the planet because terrestrial, marine, and atmospheric processes all interact in shaping them.

This project focuses on Bayelsa state, which is mostly a coastline state. The state borders a huge coastal and marine environment that is dynamic and subject to a wide range of activities that might generate potentially dangerous climatic conditions that cause environmental degradation and negatively affect both the life of aquatic species and humans. Like some other states of the Niger Delta, so much of Bayelsa’s coastal and marine environments are susceptible to coastal storms such as episodic chronic shoreline erosion, flooding, high tide, wave surge, high wind, and over-wash.

It is crucial to note that the state is also vulnerable to man-made environmental hazards resulting from oil exploration activities by multinational oil companies, whose operations, in most cases, are not in compliance with international best practices, as well as the oil bunkering activities committed by locals. These activities often lead to oil spillages which pollute the rivers, creeks, mangroves, and farmlands, hence having some negative impacts on both the aquatic and human livelihood.

However, the flood hazard to the residents and its e environmental challenges can be solved with the use of space-based technologies: Remote Sensing, GIS, and other related techniques. These techniques have proven to use powerful tools for the monitoring and analyzing of the Earth’s surface and atmosphere on a global and regional scale. The land use and land cover features such as vegetation, settlement, soil, water, forest etc. can also be seen at various scales for global and regional studies.

The modern method of monitoring terrestrial ecosystems, with remote sensing is of primary importance due to its ability to provide synoptic information over a wide area with high acquisition frequencies. Remote Sensing has been used in resource monitoring of shoreline changes, and the understanding of physical processes in the coastal environment alongside, geographic information systems (GIS).

GIS (Geographical Information System) is an important and specific spatial information system. It is the technical system for the collection, storage, management, operation, analysis, display, and description of the geographic distribution of data for the entirety of various parts of the Earth's surface (including the atmosphere) in support of computer hardware and software systems. GIS has spatial analysis capabilities, can store and manage vast amounts of complex spatial data and attribute data, and can use spatial databases for the comprehensive analysis of multiple factors with quantity, quality, and localization.

It is therefore important for the effective management and planning of the coastal and marine environment for the sustainability of the people's livelihoods because the disappearance of this livelihood for the people is on the upsurge.

1.1 Statement of the Problem

Bayelsa state in its entirety is surrounded by water; there is no locality in the study area, where streams or creeks are absent, Just like most other coastal regions around the globe. These water bodies constantly exert various degrees of impact on the environment. The area is naturally susceptible to changes such as Tidal erosion, changes in water quality, global warming resulting in a rise in sea level; increased storm frequency and severity; erosion, and increased sedimentation. The negative consequences of some of these changes to ocean and coastal characteristics, as well as to coastal communities, include: Coastal erosion, flooding, damage to coastal habitats, increased water pollution that adversely affects freshwater resources and devastation to marine life, loss of unprotected dry lands and wetlands, Loss of exclusive economic rights over extensive areas, destruction of existing economic infrastructures and commercial activities (Mmom and Chukwu-Okeah, 2011). Unhealthy vegetation limits the resistance capacity of coastlines to erosive forces (Ontario Ministry of Natural Resources, 2011). A study in Bayelsa state noted that a Periodic oil spill in the study area has resulted in the destruction of the mangrove forest which in turn led to the erosion of available shorelines especially within Sangana to Koluama.

Vegetation significantly contributes to shoreline degradation when it is removed or becomes unhealthy. In the study area, natural and human influences are all contributing to the degradation of the environment such as waves, tidal currents, severe storms, sea level rise, and the activities of the oil companies (Eniye and Ebifuro, 2016). Due to the activities of oil exploration in the area, studies have shown that the air, land, and water have all been contaminated, which has devastating effects on residents' health and livelihoods (Nenibarini and Gustaf, 2017). There is a dire need for an in-depth investigation of the coastal region of Bayelsa state with the view of characterizing the ecosystems and n monitoring the impacts of both human activities and other natural forces on the coastal environment over time, with emphasis on underscoring the influence of these factors on the sustainability of livelihoods in the study area.

1.2 Justification of the study

The Coastal and marine ecosystems are among the most important in the world providing a diverse range of flora and fauna vital to human well-being (Olalekan Adekola, 2011). Providing data and information about the values of coastal and marine resources is a major way to ensure their wise use and stem their conversion (Adekola and Mitchell, 2011). Direct drivers of change in the coastal and marine environment of Bayelsa state include changes in local land-use and land-cover, species removal or invasion introduction, eutrophication, water abstraction, and climate change.

It is predicted that with a one-meter rise in sea level, the Niger Delta could lose over 15,000 square kilometers of land by the year 2100, and if urgent action is not taken to address the problem, at least 80% of the people of the region would be displaced (Benjamin P. Horton, 2020). From this assertion, Bayelsa state is expected to lose over 2000 square kilometers by the predicted year 2100. Measures have to be put in place through adequate studies to reduce this high level of degradation for a sustainable environment.

The Coastal and Marine environmental movement in decades has resulted in higher awareness of environmental issues. However, the effect of land-use practices and community interaction with the coastal and marine environment has been understudied in developing countries like Nigeria where land surface is largely used for agriculture, grazing, and other human activities. The coastal and marine environment of Bayelsa state is changing rapidly raising concerns for the health of the communities relying upon its ecosystem services. Knowledge of the ecosystem provision is important for effective livelihood management.

To be able to proffer solutions to environmental challenges there is a great need for a convenient and reliable set of data on key parameters. Data must be acquired to see what can be done to proffer solutions to the degrading effect of the coastal environment.

In this research, the geographic information system (GIS) and Remote Sensing approach will be applied for a more concise and detailed characterization of the environment and benefits derived from the coastal and marine environment of Bayelsa to continually sustain the livelihoods of local communities.

1.3 Aim

The aim of this study is to characterize the coastal and marine environment and its impact on the residents of Bayelsa state.

1.4 Objectives of the study

The specific objectives of the study are to:

i. Characterize the coastal and marine environment of the study area, using a two-year time series for exploration.
ii. Identify the major environmental hazard in the region- flooding and asses its impact on the residence areas of the people.
iii. Survey the people's socio-economic factors present in the state and evaluate its effects on the sustainability of the people's livelihood.

1.5 Study area

Bayelsa State is one of the six states that make up Nigeria's South-South geo-political zone. It has interstate boundaries with Rivers State to the west and northwest, Delta State to the east and southeast, and The Gulf of Guinea to its south. The study area lies within latitude 40^0 45' north and longitude 60^0 45' west It covers an area mass of (10,773km^2) with a population of 2,227,981 (Wikipedia, 2025) and a population density of 158 people per sq. km which accounts for 1.2% of

Nigeria's total population. It has a riverine and estuarine setting with water bodies within the area. Its coastal and marine environment (wetland) is formed by the accumulation of sedimentary deposits transported by the rivers Niger and Benue which discharges water, sediments, and other loads across Bayelsa State and southern states of Nigeria as a whole into the Atlantic Ocean (World Bank, 1995).
The state has a **tropical monsoon climate** prevailing. The average annual temperature is 35° degrees and it has about 502 mm of rain in a year. It is dry for 205 days a year with an average humidity of 55%. As a State in the oil-rich Niger Delta, the State's economy is dominated by the petroleum industry, having one of the largest crude oil and natural gas deposits in Nigeria.
The major occupation of the people is fishing, farming, trading, and grazing. Basically, some of the features found in the region are scattered settlements, flooding, light vegetation, water bodies, swampy areas, local Abattoirs (close to settlement), dump sites on drainage channels, water type (free water), petroleum industry, etc. The major ecological zones include lowland rainforest, fresh water, swamp, and mangrove. The implication of these leads to a loss of valuable biodiversity, land, property, economic activities, and livelihood of the coastal area.

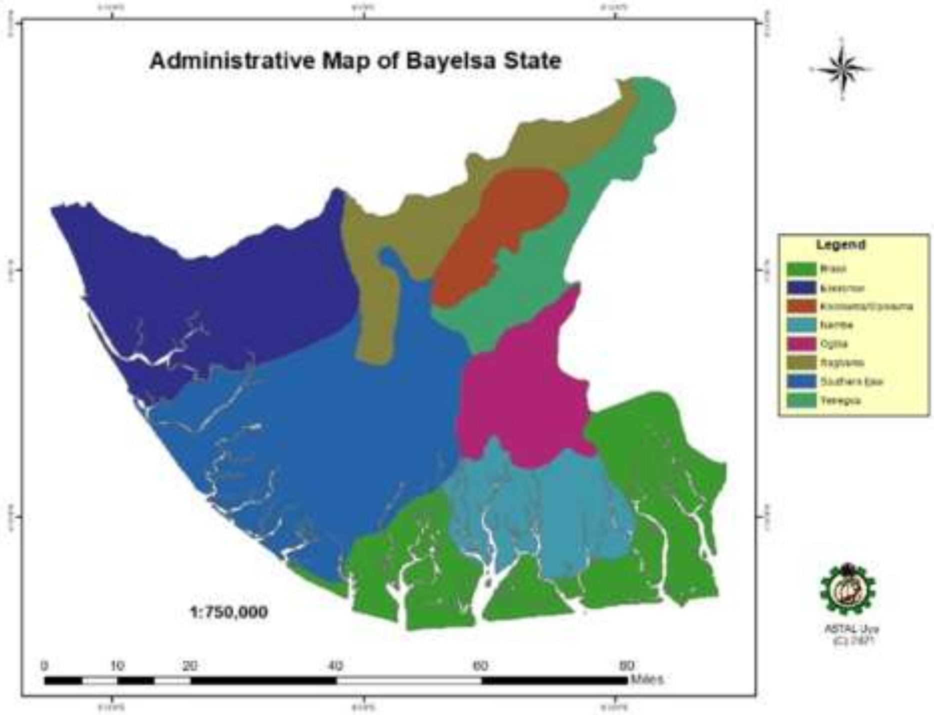

Figure 1: Map of the study area

2.0 Conceptual Framework

The key economic sectors such as agriculture, water, energy, health, wildlife, and tourism are mostly affected in Bayelsa state and have become vulnerable due to factors such as climate change, geo-hazard, ecosystem change, pollution, etc. These economic sectors are the main sources of livelihood in Bayelsa and its environs.

2.1 Ecosystem change in Bayelsa state

Environmental problem is a major threat to sustainable development (Faheem Ahmad et.al., 2020). Environmental pollution has increased within the last few decades resulting from industrialization, urbanization, population growth, deforestation emission of pollutant gases especially through gas flaring and vehicular movement. These are major sources of concern in many regions of the world. This has resulted in a decline in population, distribution and species among biological diversity.

The Niger Delta wetlands play an essential role in Nigeria. The wetland is one of the hubs of biodiversity in Africa that inhabits several endemic species (Ogbe, 2011). Many authors variously reported that wetlands are areas of fern, marsh peat land/ water with static or flowing surface water (fresh or marine or brackish) which can either be natural or artificial, temporary or permanent with a depth of less than 6 meters at low tide.

Bayelsa state's wetland is under threat probably due to human and biogeophysical effects. Intensive agricultural practices such as unrestrained soil tilling, over-grazing, logging, uncontrolled land reclamation, dam construction erosion, sea rising, alien invasion desertification, and droughts among others are having impacts on wetlands. Probably due to these effects, the ecological, economic socio-cultural, scientific, and recreational roles of the wetlands are under threat (Uluocha & Okeke, 2004; Izah et al., 2017).

The wetlands in Bayelsa and its environs are habitats for several species such as sea turtles, manatees, shoreline birds, and other threatened marine species which have been previously identified within the coastal zone of Nigeria. Though the species are threatened in the marine ecosystem. The zone is also an important source of plants with medicinal properties (Izah, 2018).

Anthropogenic activities such as logging of timber for construction works and fuel wood, cultivation, are among the factors that led to a decline in the biodiversity of Bayelsa state. Bush burning excessive exploitation/ hunting practices is another impact factor leading to a fast decline in biodiversity (Izah SC, 2018). The contamination of the local ecosystems can impact communities that rely on the said ecosystems to survive, with crops and food sources becoming poisonous or disappearing altogether as a result of food chains being destabilized.

2.2 Agriculture

Historically, agriculture (farming and fishing) was the main source of livelihood and the exploitation of natural resources was sustainable. About 65 percent of the population of Bayelsa depends on the natural environment for their livelihoods while the other 35 percent depend on remittance (Andrew, 2015).

This has resulted in the alteration of habitats, biodiversity loss, and pollution of water bodies and lands which are the most important livelihood assets of the people. In local communities, hundreds of thousands of people are affected, particularly the poorest and those who rely on traditional livelihoods such as fishing and crop farming (Haruna Abukari PhD, 2020).

2.3 Climate change

The main impacts of climate change in Bayelsa are coastal erosion and flooding. Coastal vegetation especially the mangroves has been lost to coastal erosion while settlements in this zone have been displaced by coastal erosion (Inyinbor Adejumoke A., et al., 2018). The inundation arising from the sea level will increase problems of flood, and intrusion of sea workers into freshwater sources and ecosystems destroying such stabilizing systems as mangroves and affecting agriculture, fisheries, and general livelihoods (Munday et al., 2013).

Coastline degradation is a very big problem for which little or no attention is given (Croitoru et al., 2020). Bayelsa is gradually being compressed by environmental factors such as rainfall and wind. The little available is eaten off by wave actions, tidal currents as well as human factors These issues are as important as any other factor militating against the wellbeing of man. In southern communities in Bayelsa like Sangana, Koluama, Ekeni, and Ezetu they are having problems with a shortage of available land, and their lives are seriously threatened.

2.4 Geo hazards in Bayelsa state

Bayelsa used to be green for farming and fishing with a very impressive harvest. This has therefore been reduced drastically as a result of adverse human activities in the state (Emmanuel, 2022). In Bayelsa and some other parts of the Niger Delta, communities have faced an ecological disaster. About 40 million liters of oil are spilled every year across the Niger Delta region. The resident's health and livelihoods have been affected. Vast areas of the state's waterways and mangrove swamps – one of the most diverse ecosystems in Africa have been destroyed or put at risk. Farmlands have been cloaked in oil, containing crops and exposing people to high levels of heavy metals such as chromium, lead, and mercury (Ratcliffe, 2019).

A 2019 study in Nigeria, Africa's most populous country and largest oil producer discovered that nearby oil spills increased neonatal mortality by 38.3% per 1000 live births. Further evidence suggests the effects persist for several years, with the study describing the impact as an alarming ongoing human tragedy (Anna & Roland, 2019).

On the impacts of economic activities on the environment of the Niger Delta, water bodies have been heavily polluted due to recurring incidences of oil spillage (Ana et. al., 2009). Residents of Sangana and other coastal communities in Akassa Kingdom, Brass local government area of Bayelsa state have wailed out over the loss of livelihood affected by the alleged unceasing leakage of crude oil into the environment from offshore facilities in the area. The troubled communities occupy the southernmost part of Bayelsa.

3.0 Methodology

The procedure and process that was involved in carrying out the research comprising, the data to be used, tools, manipulation, and analyses is given below.

3.1 Materials

Data

i. Satellite imagery (Landsat8 Imagery)

ii. Data from detailed field verification exercise using the Global Positioning System (handheld GPS)

iii. Geological map

iv. Topographical map

v. Administrative map

Software

i. ERDAS 10.5
ii. ArcGIS 10.5
iii. Microsoft Office Excel 2010
iv. Microsoft Office Word 2010

Hardware

i. High-speed Processing System
ii. Hand-held global positioning systems (GPS) units
iii. Plotter
iv. Printer
v. External hard disks

3.2 Method

Landsat8 imagery was selected to produce a Land-Use Land-Cover (LULC) and shape file of Bayelsa state which stands as the study area. It was created from a Nigeria shape file, which was extracted as an input parameter for the hydrological model in this study.

GIS data used in this study includes topographical database, GPS data, and Digital Elevation Modeling (DEM). The data were collected from the field in the process of ground-truthing, and also from the United States Survey Government (USSG) website. The topographical database includes objects such as buildings and constructions, traffic route networks, LULC, water systems, administrative borders, and elevation. DEM at 3m resolution was utilized to delineate areas prone to flooding.

i. Personal Geodatabase

Two types of geodatabase architectures are available under ESRI's ArcGIS package: Personal Geodatabase and Multiuser Geodatabase. In this study, a personal geodatabase was implemented to store the necessary data that could be applied to the final analysis for the designed objectives.

ii. Field Survey

During the field survey, the necessary information had been taken and registered. Ground truths of major damages of the 2013 flood were collected using GPS to compare it with the flood hazard and flood risk map generated in this study. In addition, the ground verification for the land-use/land-cover map was conducted.

iii. Satellite Image Processing

Satellite images of Landsat 8 sensor of 2013 TM and 2020 ETM, path 189 and row 57, which were acquired on July 28 and June 30 respectively, (with a map projection of UTM_ zone 32N, and datum WGS_ 84) were used for the land-use/land-cover mapping and change detection processes. These images were stacked in the ArcGIS 10.6 software and subset by the boundary of Bayelsa State. Using Digital Image Processing analyses, three steps were considered:

a) Pre-processing
b) Image Enhancement
c) Image classification

The 2013 image was classified and used as a factor map for land-use/land-cover. The 2020 classified image was used for land-use/land-cover change detection.

Six classes of LULC were identified: (1) water bodies (rivers, streams, lakes, wetlands, canals); (2) built-up areas (roads, beach sand, houses, public service places, public administrative, pavement, concrete); (3) built-up areas with flood (flooded road, flooded beach sand, flooded public service place) (4) Farmlands (all types of farm visible on the imagery); (5) Light Vegetation (vegetables, open fields and grass/ parks) (6) Dense Vegetation (Tall trees, Palm plantations, rubber plantations). The overall classification accuracy was 85%.

iv. Social-economic modeling

In other to map out the mineral resources, and Agro raw materials in the state, questioners were administered to indigenes as well as non-indigenes to acquiesce their geo-spatial spread or distribution across the state. Geospatial information was also gathered using geological and administrative data of the study area.

v. Data Merging and GIS Integration

These procedures were used to combine all the image data for a given geographic area with other geographically referenced data sets for the same area in the context of a GIS.

4.0 Result

The results in Maps, from all the objectives outlined in this study are shown below in Figures 2 – 19. Also in tables from, Tables 1-7.

i. Maps

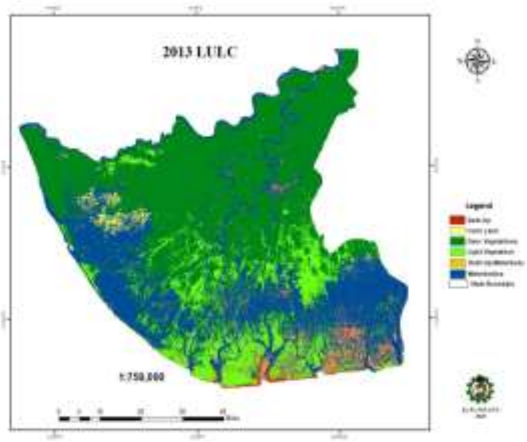

Figure 2: Showing LULC of the state in 2013

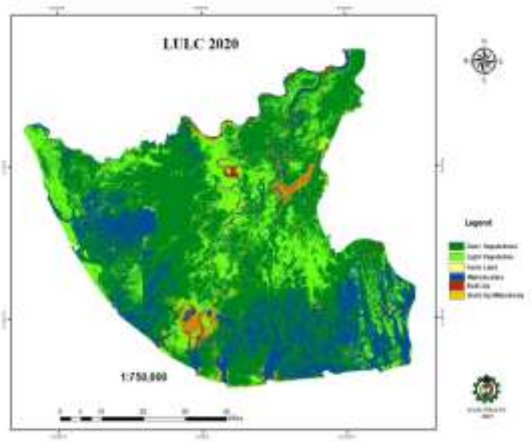

Figure 3: Showing LULC of the state in 2020

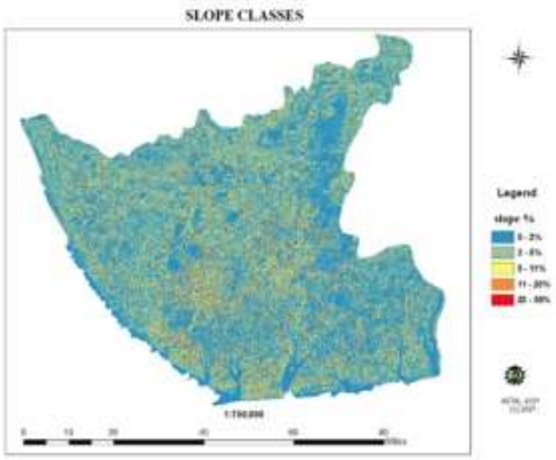

Figure 4: Slope map of Bayelsa State

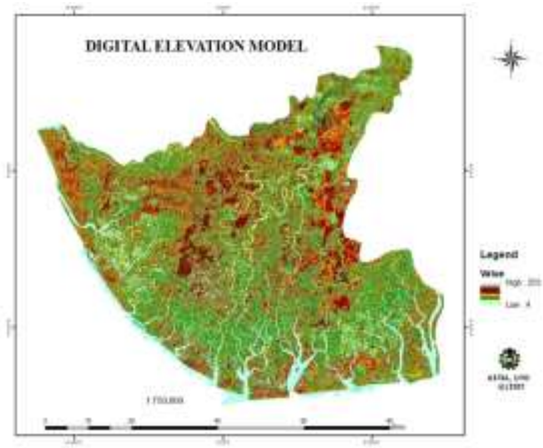

Figure 5: DEM map of Bayelsa State

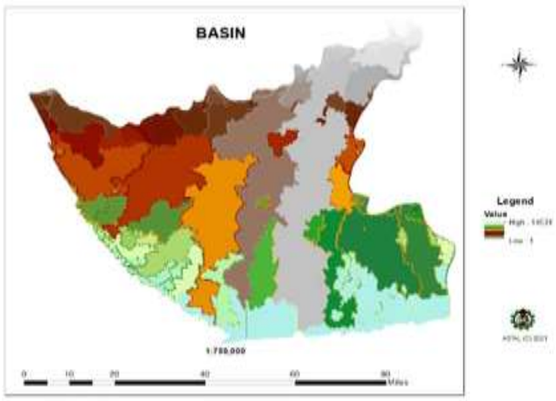

Figure 6: Basin map of Bayelsa State

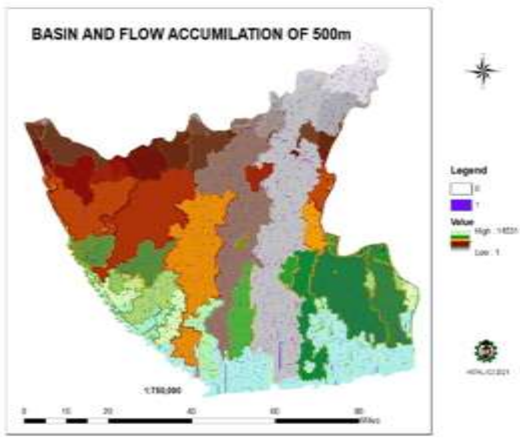

Figure 7: Showing Basin and Flow accumulation

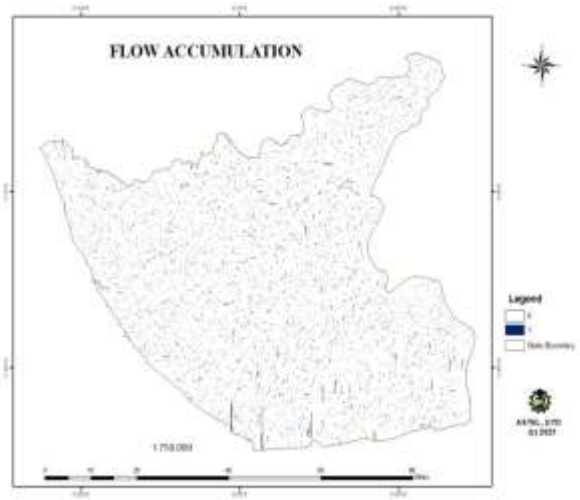

Figure 8: Showing Flow accumulation of 500 meters

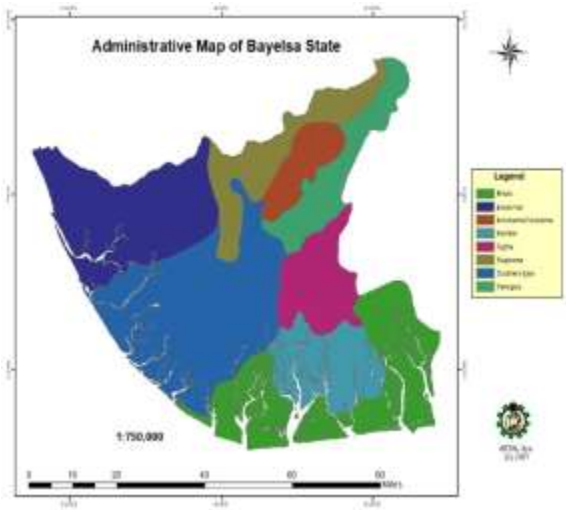

Figure 9: Administrative map of Bayelsa State

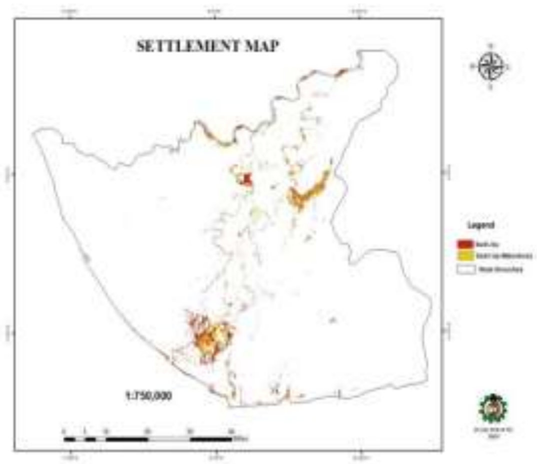

Figure10: Showing Flood in built-up areas in 2020

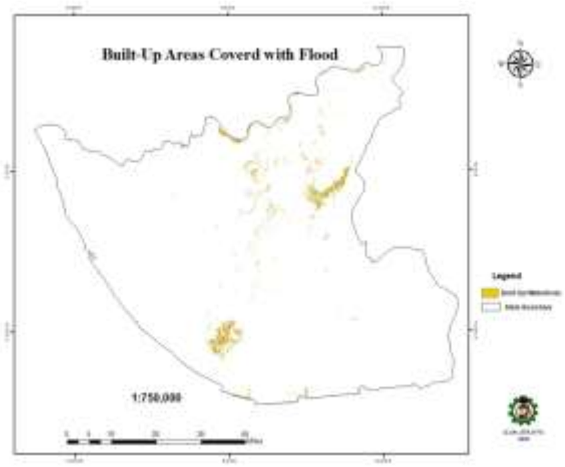

Figure11: Showing Flooded and non-flooded in 2020

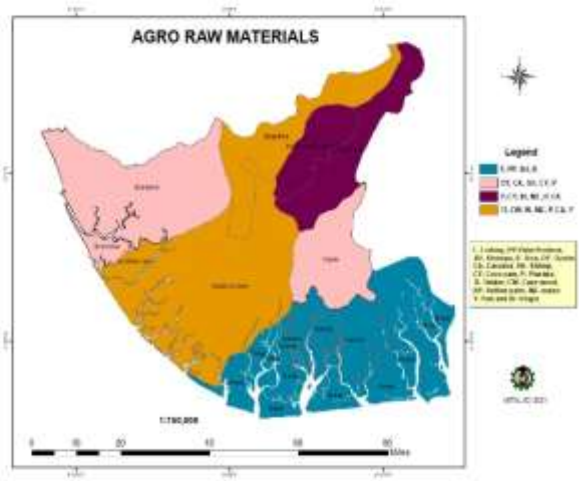

Figure 12: Showing Agro raw Materials in the state

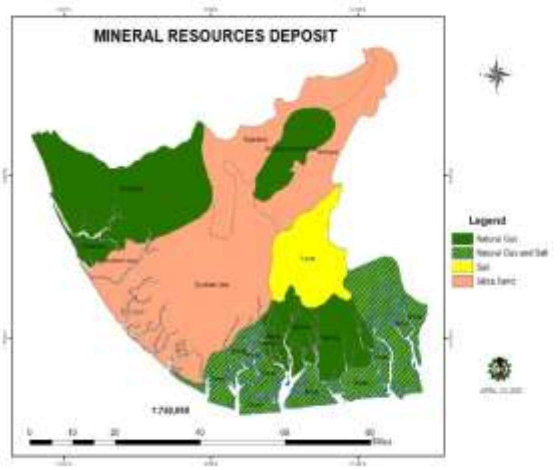

Figure 13: Showing mineral deposits in the state

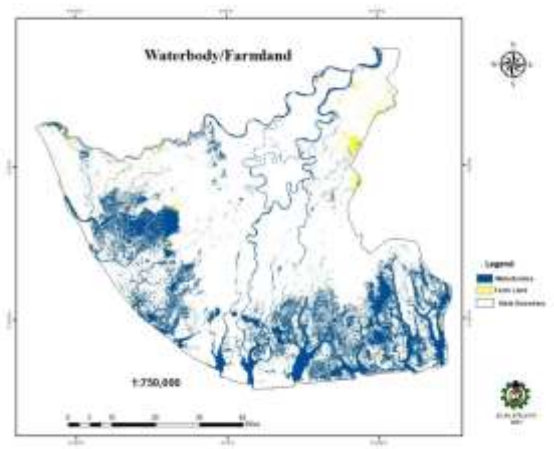

Figure14: Showing waterbody and Farmland in 2020

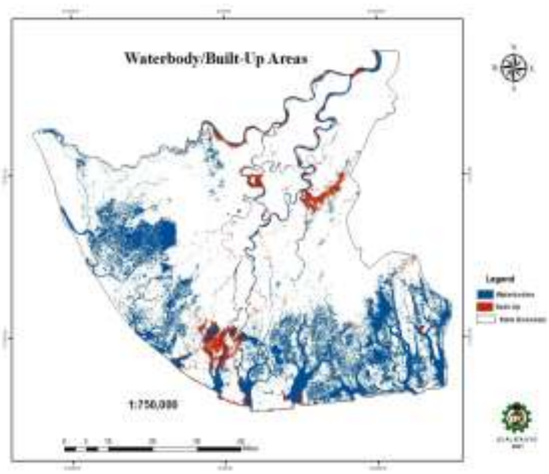

Figure15: Showing waterbody and Built-up in 2020

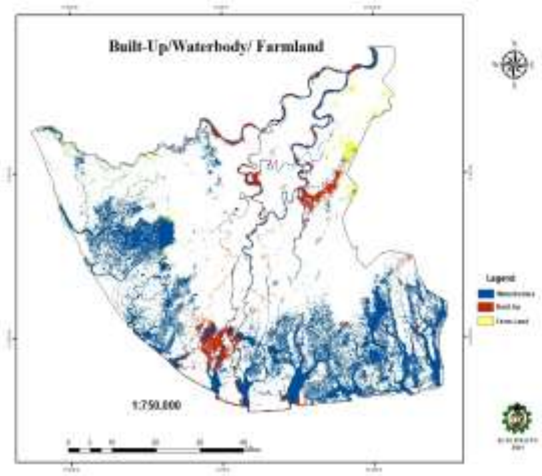

Figure 16: Showing waterbody and Built-up and Farmland in 2020

ii. **Tables and Charts**

Table 1: 2013 LULC class counts.

S/N	Classes	No. of Counts
1.	Builtup	52,788
2.	Buitup with Water	245,682
3.	Lighter Vegetation	837,515
4.	Dense Vegetation	3,115,941
5.	Farmland	97,796
6.	Waterbody	2,080,074

Table 2: 2020 LULC class counts.

S/N	Classes	No. of Counts
1.	Builtup	168,658
2.	Buitup with Water	121,466
3.	Lighter Vegetation	1,127,074
4.	Dense Vegetation	2,485,480
5.	Farmland	531,873

6.	Waterbody	1,995,245

Table 3: Surface area cover in 2013

S/N	Classes	Area covered in m²
1.	Builtup	11,877,300
2.	Buitup with Water	55,278,450
3.	Lighter Vegetation	188,440,875
4.	Dense Vegetation	701,086,725
5.	Farmland	22,004,100
6.	Waterbody	468,016,650

Table 4: Surface area cover in 2020

S/N	Classes	Area covered in m²
1.	Builtup	37,948,050
2.	Buitup with Water	27,329,850
3.	Lighter Vegetation	253,591,650
4.	Dense Vegetation	559,233,000
5.	Farmland	119,671,425
6.	Waterbody	448,930,125

Table 5: Change Detection

S/N	Classes	Area covered in m²
1.	Builtup	26,070,750
2.	Buitup with Water	-27,948,600
3.	Lighter Vegetation	235,150,775
4.	Dense Vegetation	-141,853,725
5.	Farmland	97,667,325
6.	Waterbody	-19,086,525

Table 6: land use land cover percentage coverage of years 2013 and 2020

S/N	Classes	2013 LULC %	2020 LULC %
1.	Builtup	1	3
2.	Buitup with Water	4	2
3.	Lighter Vegetation	13	18
4.	Dense Vegetation	48	39
5.	Farmland	2	8
6.	Waterbody	32	31

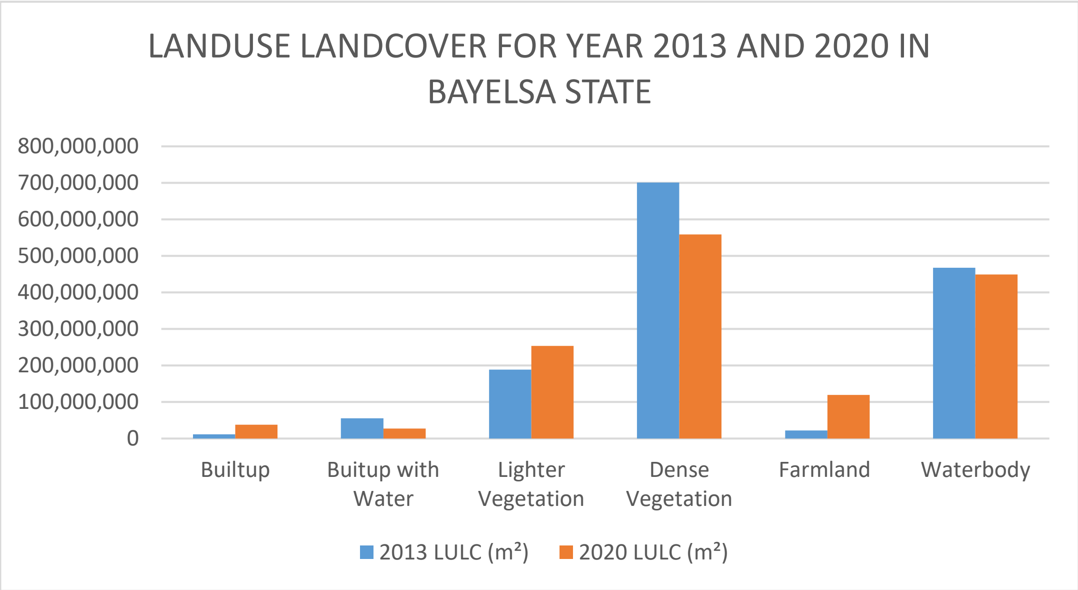

Figure 17: Histogram showing the LULC Change distribution of Bayelsa state years 2013 and 2020

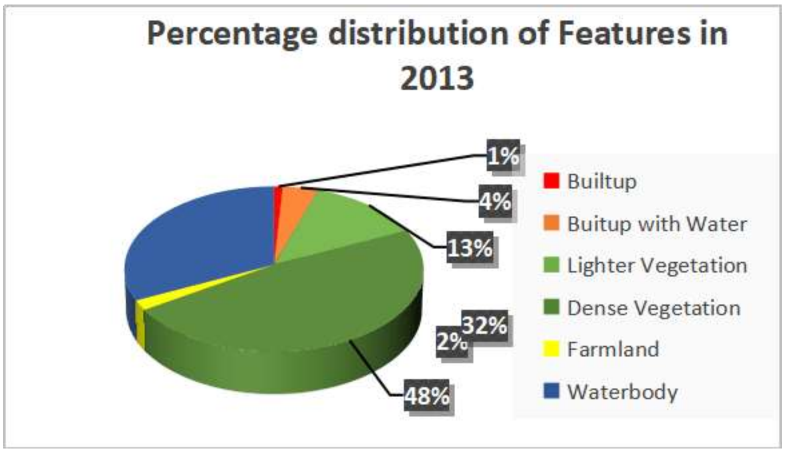

Figure 18: Pie chart showing percentage distribution in 2013

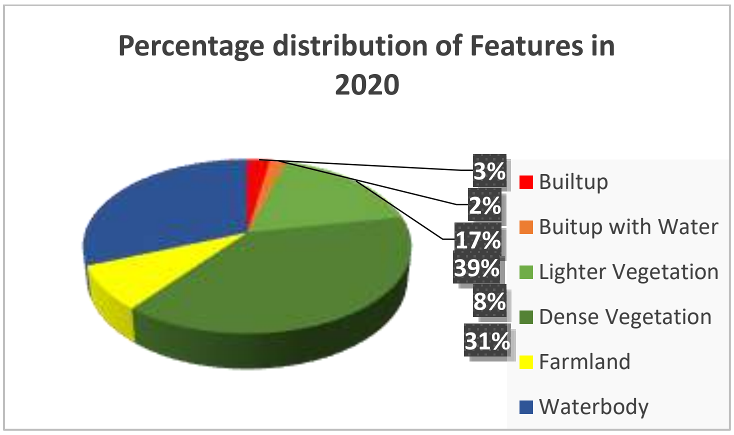

Figure 19: Pie chart showing percentage distribution in 2020

4.1 Discussion

4.1.1 Environmental characterization

The combination of the Iso Cluster and Maximum Likelihood Classification was used in image classification. Result shows that in 2013, the counts for (Builtup was 52,788), (Builtup with water, 245,682), (light vegetation, 837,515), (dense vegetation, 3,115,941), (farmland, 97,796) and (waterbody, 2,080,074) as shown in table 1 above. In 2020 the count for (built-up was 168,658), (built-up with water, 121,466), (light vegetation, 1,127,074), (dense vegetation, 2,485,480), (farmland, 531,873) and (water body 1,995, 245) as shown in table 2 above.

i. LULC 2013

In the year 2013, the areas covered by each class were; (Built-up 11,877,300m), (Built-up with water, 55,278,450m), (light vegetation, 188,440,875m), (dense vegetation, 701,086,725m), (farmland, 22,004,100m) and (waterbody, 468,016,650m) respectively. This is shown in Table 3 above.

ii. LULC 2020

The result shows that in the year 2020, the areas covered by each class were; (Built-up 37,948,050m), (Built-up with water, 27,329,850m), (light vegetation, 253,591,650m), (dense vegetation, 559,233,000m), (farmland, 119,671,425m) and (waterbody, 448,930,125m) respectively. This is shown in table 4 above.

iii. Change detection

The result shows the built-up areas gained 26,070,750m area coverage in 2020, while built-up areas with water on the surface lost an area coverage of 27,948,600m. Lighter vegetation gained 235,150,775m and dense vegetation lost 141,853,725m. Farmland increased to 97,667,325m while waterbody lost 19,086,525m. This is represented in Table 5 above. Also for further explanation results can be cited in figures 17,18 and 19.

4.1.2 Flooding analysis

A slope map, indicated as a percentage slope, for the study region was computed from the DEM of the basin. For analytical goals, the slopes were classified into 5 classes as shown in Figure 4 above: namely, less than 2, 0 - 2% which is very flat, less than 5, 2 – 5% which shows moderately flat, less than 11, 5 – 11% which is flat, less than 20, 11 -20% that shows high land and greater than 20, 20 and above% shows very high land. This makes up 64%, 8%, 15%, 9% and 4% of the study area, respectively.

A raster delineating all the drainage was created known as a "Basin". It shows that Bayelsa state has nine (9) major basins as seen in Figure 6, with more flow accumulation draining into Brass, Nambe, Southern Ijaw, Ekeremor, Ogbia, Sagbama, Kolokuma/Opokuma, and Yenegoa local government area respectively. The largest and longest basin with less flow accumulation falls between the part of Kolokuma/Opokuma, Yenegoa, Ogbia, Nambe, and Brass while Nambe and Brass have the highest accumulating basin. A raster calculator was used to calculate a flow direction within the average of 500m. This can be obtained from ArcGIS software; ArcToolbox, Spatial Analyst Tools, Map Algebra, and the Raster Calculator.

This was to show the steepest cell in which water may likely run into. The class was divided into two classes 0 and 1. Where 0 is the highest surface and 1 is the steepest next cell as seen in Figure 8. The result shows that the high land covers about 342,939,620m² and the area of flow accumulated covers about 1,103,764,480m² giving it a total of 1,446,704,032m² of the state's land mass which makes the terrain a flood-prone area.

That is to say that the high land occupies 23.7% of the land mass while the low land with accumulated water occupies 76.3% of the same land mass when it is being calculated with the average flow of 500m.

Querying the area of settlements and area covered by the flow of water at an average flow accumulation of 500m, as seen in figure 16, the result further tells that about 85% area of settlements in the state is being affected by the accumulation of water runoff. This leads to flooding affecting the livelihood and as well as resulting in loss of lives and property, as seen in figures 10 & 11.

4.1.3 Social-economic activities in the study area

The state is heavily endowed with lots of mineral resources and natural Agro raw materials such as;

i. Mineral Resources: Natural Gas, Crude Oil, Salt and Silica Sand. Where we have major deposits of natural gas in Brass, Ekeremor, Kolokuma/Opokuma, and Nembe LGA. The crude oil is mostly found in Oloibri, in Ogbia LGA. Salt is seen more in Brass and Silica sand and more deposited in Southern Ijaw, Sagbama, and Yenegoa LGA.

ii. Agro Raw Materials: Fish, Oyster, Shrimps, Cassava, Coco yam, Plantain, Timber, Cane wood, Raffia Palm, Irivingia (Ogbono), Maize, Palm Produces, Rice, Yam, Sugar cane, Sea foods etc. are also found in the state. The table below shows their distributions in larger quantities.

Table 7: Agro Produce in Bayelsa State

S/N	STATE	AGRO PRODUCE
1	Brass	Palm oil and kernels, cassava, taro, plantains, oysters, shrimps, and rice.
2	Ekeremor	Rice, sugar cane, seafood, plantain, yam.
3	Kolokuma/Opokuma	Plantain, maize, sugar cane and cassava.
4	Nambe	Irvingia, maize, coco yam, plantain and cassava.
5	Ogbia	Irvingia and maize.
6	Sagbama	Maize, raffia palm, palm produce and yam.
7	Southern Ijaw	Rice, fish, cane wood, and cassava.
8	Yenegoa	Fish, plam produce and cassava

The table gives a detail of the various agricultural produce of the people across each local government area. This is also in line with the people's occupation, showing a rich produce of the study area. The region being rich in produce has also been affected by environmental issues, affecting the factors of production, thus causing a depreciating economy for the people. The prices of items being sold have also gone up so high, based on questionnaire input, thus causing real hardship for the people. Also, the people's livelihood in terms of their source of living has been greatly affected hence the low turnout of their produce due to how the coastal and marine environment has been affected, as seen in figure 16 showing where the people reside being flooded as well as the farmlands.

Some occupations mainly fishing and farming have been abandoned due to low yield in the productivity of sea foods and the disappearance of activities on farmlands, this can be observed from the results above in Figure 14.

In summary:

In the forest, there is an observed reduction in tree canopies in the study area. While water body volume is decreased, the waterbody in the region has been badly affected due to the presence of contaminants. This can be explained by why there is a decrease in fishing activity in the area. Due to development, several buildings have taken over farmlands. The proximity of the Atlantic Ocean has promoted flooding which has caused the area prone to erosion, affecting mostly settlements along the shoreline. This has also affected the roads, schools, markets, hospitals, and other facilities. Food production decreased leading to price increases, causing an imbalance in the economy. Fish harvesting was affected due to increased flooding and saltwater intrusion in the area, which in turn pretentious the occupation of farmers and fishers hence causing their migration to other places for greener pastures.

5.0 Recommendation

i. The poor rural farmers and fishers should be given the necessary support through incentives to encourage their drive for sustainable food security in the study area.

ii. There should be strengthened environmental laws to protect the coastal and marine environment.

iii. The result from this study shows that the ecosystem is depreciating in vegetation.

iv. Effective planning and monitoring of the area is vital. New urbanization should be introduced in the most suitable highland to reduce the risk of flooding in the environment.

5.1 Conclusion

The use of Remote sensing and GIS has been proven as a tool for understanding the drives of persistent flooding in Bayelsa. A major fact drawn from the study is that the state is a relatively lowland and it is prone to environmental issues being a coastal and marine area. According to the findings, there is a higher production of agricultural products than seafood since more people migrated from the lowlands to the highlands to live and concentrated more on farming, leaving the lowlands with fewer people and little to no fish cultivation. However, flooding has also been a factor for food production decrease and this has brought about increased food prices, with the poor inhabitants being affected by this. Also, the issue of flooding has caused hardship for the people in terms of their lives and property. The coastal and marine environment of Bayelsa state has affected the livelihood assets of the people in one way or the other and has continued to impact their sustainability negatively.

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