

## **GEOSPATIAL ASSESSMENT OF 32-YEAR CHANGES IN VEGETATION COVER OF SOME MANGAL-RAINFOREST ECOTONE IN PARTS OF ASARAMA, ANDONI, RIVERS STATE.**

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### **ABSTRACT**

The use of geospatial technologies, especially the GIS, has been helpful in monitoring and detecting changing patterns in various vegetation zones. The present study on Asarama study location site was on the basis that land use ecology of anthropogenic and natural influences have constantly led to changes in the vegetation ecotypes with attendant depletion and destruction in the study area. The study was aimed at evaluating the feasibility and use of geospatial tools in assessing these changes within the varying vegetation ecotypes (mangrove, ecotone and rainforest) spanning over 32 years at 16 -year intervals. Results of the 1986 Landsat imagery revealed maximum vegetal trend condition across the vegetation ecotypes that were impacted by anthropogenic activities (farming, logging, deforestation, road/bridge construction and urbanisation) with consequent vegetal cover change, loss and depletion as depicted in 2002 and 2018 Landsat imagery, exemplified in the normalised difference of vegetation index (NDVI) and normalised difference of build-up index (NDBI). The greener parts in the NDVI reflecting a higher value showing a healthy vegetal cover and the blue parts of NDBI with high reflectance values revealed areas of anthropogenic influence alterations. This, by implication, signifies the measure of the vegetation health condition and anthropogenic alteration, respectively.

**Key words:** Spatial; data-mining; landsat; anthropogenic; vegetation

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### **INTRODUCTION**

Vegetation is an important part of the ecosystem that reflects the effects of the entire environment. It is formed by plant species growing as a result of a long development process consistent with the places they inhabit and constitutes a fundamental part of ecosystems (FGDC, 2005). Edwin-Wosu (2020) described vegetation as an array of plant species or collective plant cover over a certain region. There are numerous vegetation types in the world as well as Nigeria and these vegetation types result from the effects of the various environmental factors on sets of species which cohabit in a determined space and period. In 1991 it was estimated during the national census that 25% of Nigerian population lives within the Niger Delta region which totals about 20 million people; this approximately rose to over 30 million people in 2005 (Twumasi and Merem, 2006; Uyigie and Agho 2007; Kadafa, 2012). It can be deduced that as the population of a country or place increases so is the increase of ecological demand on its vegetation zone. This results in ever-increasing changes and succession in the vegetation system of the ecozone.

The increasing depletion of vegetation cover and change in its dimension within the Niger Delta are basically the functions of two major ecological trends involving anthropogenic and natural influences. Anthropogenic activities include hydrocarbon exploration / exploitation and its emissions, domestic logging, dredging, land use developmental strive, pastoralism, non-systematic agronomic activities and intense agricultural practices (use of chemical-based fertilizers and pesticide), urbanisation, industrialisation and deforestations (Uluocha and Okeke, 2004; Fashae *et al.*, 2017; Izah, 2018). The natural factors include climate change and fire threat which are both noted as major threats to the existence of vegetal cover (Fashae *et al.*, 2017). However, man steadily and constantly alters his physical environment to please himself thus changing the natural vegetation faster via anthropogenic

processes compared to natural processes (Bathia, 2006). Anthropogenic and natural influences on vegetation pose a great need for changes within them especially those within the Niger Delta to be detected and analysed. It is important to note that these change agents do not function in isolation but in synergy with another agent of environmental vicissitude.

It is important to detect changes in vegetation by monitoring and managing natural resources in any vegetation complex. It has been stated that change detection involves studying and understanding processes and pattern of vegetation cover change, causes and human response to the cover change (IGBP / IHDP, 1999). Smith *et al.* (2010) stated that prior to the 21st Century geospatial application, change detection analyses were made possible using only field measurement estimates, ground truthing, analysis of historical maps and aerial photographs which had demerits like high cost and time-consumption amongst others. However, changes can presently be detected using new, improved and emerging technological tools which are mostly based on satellite geospatial technologies. Change detection programmes of geospatial tool at the continental, regional and local scales have been applied to vegetation zones due to their nature and the ease at which they are being analysed for several purposes. The significance of satellite-based geospatial technologies (Global Positioning System [GPS], Remote sensing and Geographical Information System (GIS) are numerous. Ademiluyi *et al.* (2008) had emphasised their predominant use in vegetation analysis especially their effectiveness in monitoring the changing patterns of vegetation, ecological systems and its management have proven to be faster, less stressful, less cumbersome, time-effective and more powerful compared to the sole usage of pre-historic maps and ground measurements. These geospatial technologies are automated and have been used in detecting position and changes in positioning of certain earth features over a period of time even in the Niger Delta (Edwin-Wosu *et al.*, 2019).

The study was premised on the fact that man-made or anthropogenic and natural influences constantly lead to occurring changes within any vegetation or ecosystem (Uluocha and Okeke, 2004; Fashae *et al.*, 2017; Izah, 2018); this led to vegetal depletion or destruction. There is the need to detect and analyse the changes which occur within any vegetation in order to determine the extent or degree to which vegetal resources are harnessed, evaluate the trend of changes, if possible forecast future changes (Uphanday, 2009) and know the conservation strategies to implement where necessary. Furthermore, it has been observed that there is paucity of interest in detecting and analysing vegetal cover changes especially within the tropical forest regions of Nigeria using GIS analysis (Ademiluyi *et al.*, 2008; Njike and Daniel, 2013). This study was aimed at evaluating the use and feasibility of geospatial tools in assessing changes within the varying vegetation types spanning over a period of 32 years at 16 year-intervals with the objective of evaluating the possible land-use ecology and causes of changes within the Mangal-tropical rainforest ecotone in Asarama, Andoni, Rivers State.

## MATERIALS AND METHODS

### *Description of the Study Area, Location and Site*

Rivers State, located between longitudes 6°23"E and 7°6"E and latitudes 4°18"N and 5°45" N of the equator, is part of the Niger Delta in Nigeria (Fig. 1). The State is bounded to the East by Imo River and Akwa-Ibom, to the West by Bayelsa State, to the North by Imo State and Abia State and to the South by the Atlantic Ocean (Edwin-Wosu and Edu, 2013). The area is characterised by mangrove forest, coastal barrier islands, freshwater swamp and the tropical rainforest (Izah, 2018) and a tropical hot monsoon climate due to its latitudinal position associated with heavy rainfall (2000 mm to 2500 mm); average temperature (23.00 - 42.60°C) all year round and a relative humidity of between 65 % and 96.80 % (Kuruk, 2004; Eludoyin *et al.*, 2011). Its relief is generally lowland with an average elevation of 20 m to 30 m above sea level (Ayoade, 1988; Alagoa, 1999; Kuruk, 2004; Eludoyin *et al.*, 2011). Rivers State consists of twenty-three (23) local government areas including the study location, Andoni (Edwin-Wosu and Anaele, 2018).

Andoni study location with its geographical situate at Latitude 4°32'57"N and Longitude 7°26'47"E is bordered to the north by Khana; to the west by Bonny; to the east by Opobo / Nkoro local government area and to the south by the Atlantic Ocean. It has 11 towns / communities including Asarama study site (Fig 2.2).

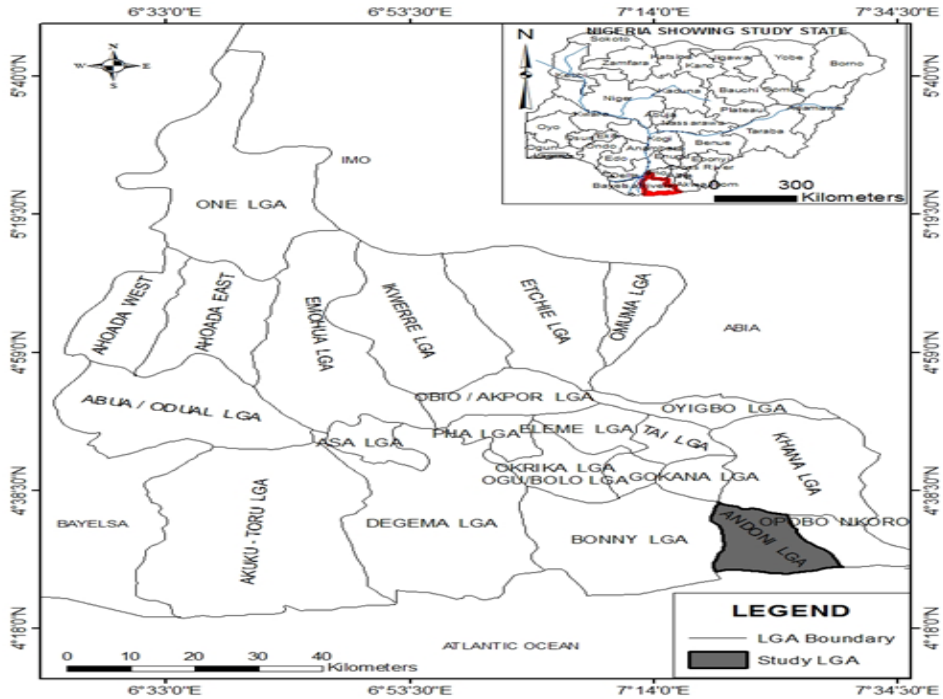


Fig.1. Rivers State showing Andoni study location

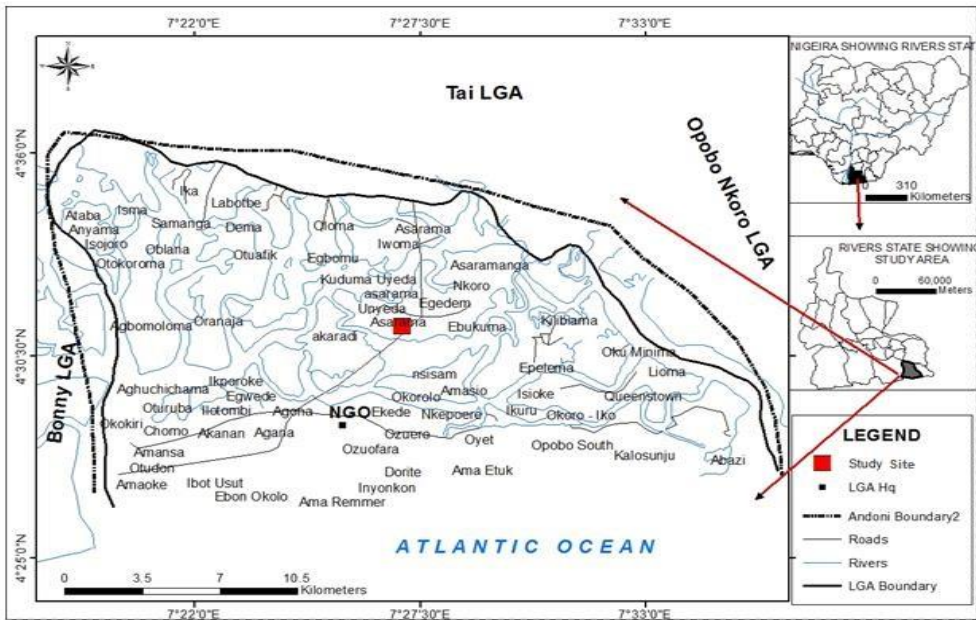


Fig. 2. Andoni study location showing Asarama Study Site

### Land Use Ecology/Human Resource Interaction

Based on the reconnaissance survey, most of their livelihood depends on the vegetation of the study location. Hence the degree of land use ecology and human resource interaction with the sampled plots of the study sites, a participatory Rapid Appraisal (PRA) via personal interviews/discussions, Focused Group Discussion (FGD) and Key Informant Interviews (Edet *et. al.*, 2017; Edwin-Wosu and Anaele, 2018) through actual observation of natural and human disturbances and intrusions and direct observational and ground-trothing was carried out to acquire information on the trend and condition of the vegetation of the study area.

### 2.3 Geospatial Data Collection and Analysis

#### GIS and Satellite Imagery

Satellite based geospatial technologies which include global positioning system (GPS), remote sensing and Geographical Information Systems (GIS) were all used in the generation of vegetal cover maps of the sample plots at the study site within the period under consideration (1986-2018). Using the GPS (Garmin etrex 20 GPS model) for georeferencing of sample point, coordinates were taken at different points in the sample plots to generate data (Table 1). Landsat images were derived from the shutter radar topographic mission map showing vegetal cover across space.

#### NDVI Analysis

The digital number of imageries was converted to get their reflective index or value for each pixel within the study location. This aided in the acquisition of the Normalised Difference Vegetation Index (NDVI). The NDVI was used to ascertain the extent of greenness in the study location. In generating the NDVI, the Landsat imagery was imported into the ArcGis platform where it was spatially analysed using the NDVI formula:

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Where RED and NIR are the spectral reflectance measurements acquired in RED (Visible and near-infrared region) which takes the value between 0.0 and 1.0 and also varies between -1.0 and +1.0.

Table 1: Georeferenced coordinates of the vegetal ecotypes

Sampled Plot Transects	Mangrove Coordinates		Ecotone Coordinates		Rainforest Coordinates	
	Longitude (E)	Latitude (N)	Longitude (E)	Latitude (N)	Longitude (E)	Latitude (N)
Transect 1	7.46151°	4.52056°	7.46144°	4.52083°	7.46164°	4.52057°
	7.46158°	4.52050°	7.46160°	4.52073°	7.46142°	4.52096°
	7.46144°	4.52083°	7.46164°	4.52057°	7.46144°	4.52091°
Transect 2	7.46160°	4.52058°	7.46152°	4.52068°	7.46153°	4.52041°
	7.46169°	4.52052°	7.46144°	4.52054°	7.46131°	4.52079°
	7.46152°	4.52068°	7.46153°	4.52041°	7.46133°	4.52079°
Transect 3	7.46132°	4.52064°	7.46121°	4.52054°	7.46140°	4.52030°
	7.46140°	4.52069°	7.46131°	4.52038°	7.46114°	4.52066°
	7.46121°	4.52054°	7.46140°	4.52030°	7.46121°	4.52063°
Transect 4	7.46124°	4.52065°	7.46115°	4.52038°	7.46127°	4.52019°
	7.46131°	4.52060°	7.46121°	4.52025°	7.46101°	4.52058°
	7.46115°	4.52038°	7.46127°	4.52019°	7.46104°	4.52053°
Transect 5	7.46110°	4.52040°	7.46101°	4.52024°	7.46119°	4.52004°
	7.46115°	4.52035°	7.46110°	4.52021°	7.46087°	4.52045°
	7.46101°	4.52024°	7.46119°	4.52004°	7.46098°	4.52040°

## RESULTS

### LAND USE ECOLOGY

The results of the participatory Rapid Appraisal (PRA) via personal interviews/discussions, Focused Group Discussion (FGD) and Key Informant Interviews as well as direct observation and ground-trothing revealed that vegetal changes have occurred over the years due to the numerous benefits and high level ecological demand derived by the indigenous inhabitants of the vegetation zone studied. Information recorded showed that the area has remained the largest fishing settlement in Rivers State characterised by pockets of satellite structures by fish farmers. The Asarama community is characterised by major human activities in the locality involving land and water transportations using cars, motor-bikes and boats, fishing with fish nets, gears and fish traps. Fishing, farming and trading, and the picking of periwinkle, crab and lobster are the major livelihoods of members of communities in Andoni area, Rivers State. Artisanal fishing such as aquaculture and / or mariculture of oysters (*Castrostreia* sp) and periwinkles (*Tympanotonus fuscatus* var. *Radular*) is predominantly the main traditional occupation of the people and is majorly carried out by men and women folks. At low ebbing tides particularly between 0830 hr and 1000 hr some of the locals were often engaged in unsystematic periwinkles picking or harvesting without being regulated. Artisanal illegal local refinery of petroleum products was observed far upstream off the estuary at the north-western bank. Other major activities in the area include fish and coconut smoking. However, there are micro-scale businesses of open and lock-up shops among various homes in the community coupled with other forms of urbanisation as well as the road and bridge construction leading to steady vegetal cover depletion.

### VEGETAL COVER IMAGERY

Three imageries were derived from Landsat images to detect vegetal cover changes of the study location site (rainforest, ecotone and mangrove study sites) over space for a period of 32 years from 1986-2018 at sixteen (16)-year intervals.

#### Satellite Imagery of 1986

The mangrove vegetation zone dominated the North-Eastern part of the study location; the ecotone stretched across the study location and the rainforest zone dominated the western part of the study location (Fig 3.1).

#### Satellite Imagery of 2002

The places occupied by rainforest in 1986 were impacted by anthropogenic activities which led to the decline in rainforest vegetation zone across space (Fig 4.). Rainforest vegetation dominated the North stretching towards the North-Eastern part of the study location; the mangrove vegetation now dominates the South-Western part of the study location stretching towards the South-East; ecotone stretched across the study location between the mangrove and rainforest vegetation while anthropogenic alterations occupied the North-West spanning towards the North encroaching into the Rainforest vegetation.

#### Satellite Imagery of 2018

Anthropogenic alterations can be seen in clusters and pockets of varying sizes throughout the study location (Fig 5). The rainforest vegetation dominates the centre of the study location stretching from the south towards the North. Mangrove vegetation encompasses roundabout the rainforest and water bodies surround the mangrove. The ecotone occupies the North West area of the study area majorly.

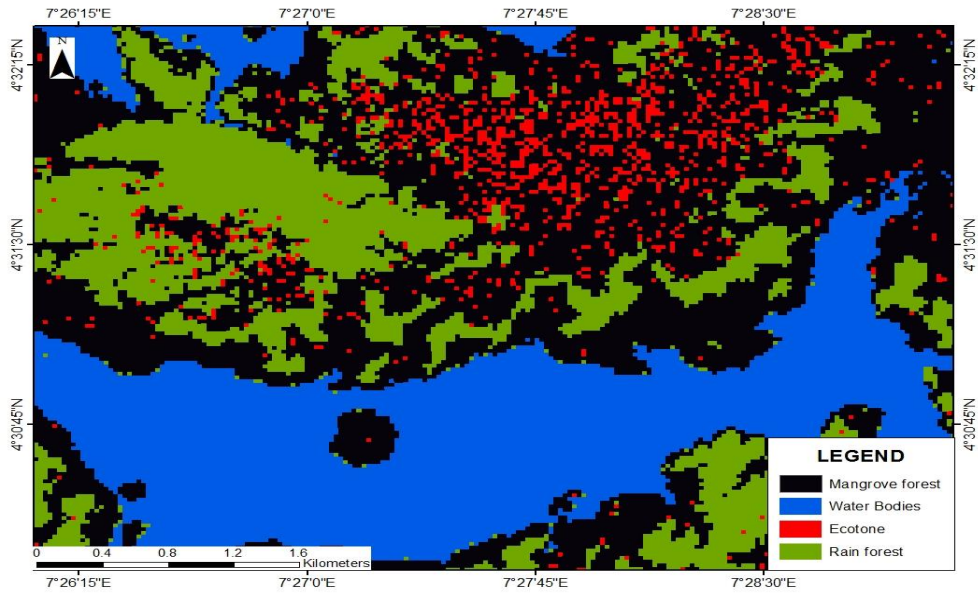


Fig. 3: Satellite imagery of vegetal cover change of the study location site in 1986 (Source: Landsat 8 (OLI) Images)

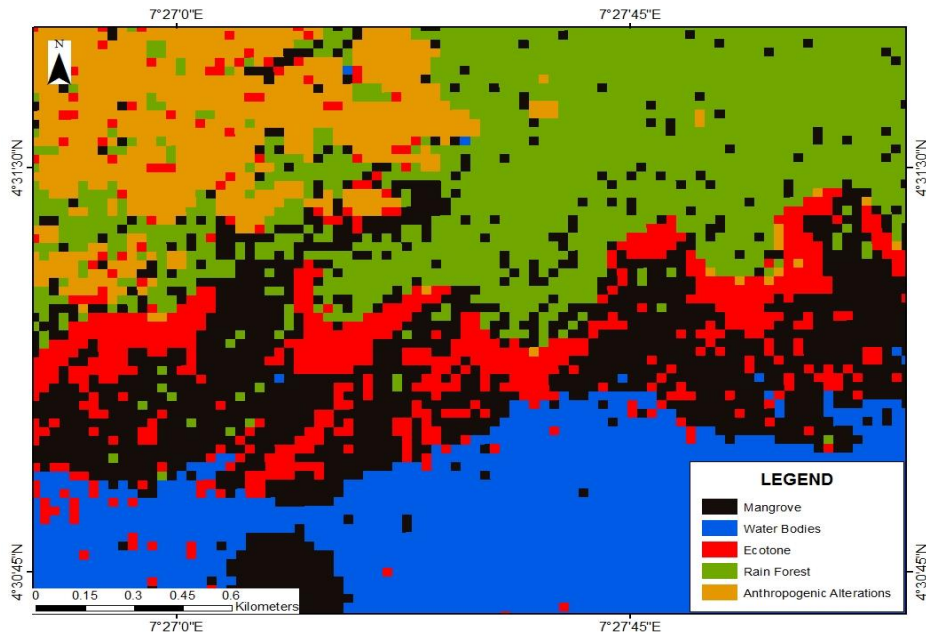


Fig.4: Satellite imagery of vegetal cover change of the study location site in 2002 (Source: Landsat 8 (OLI) Images)

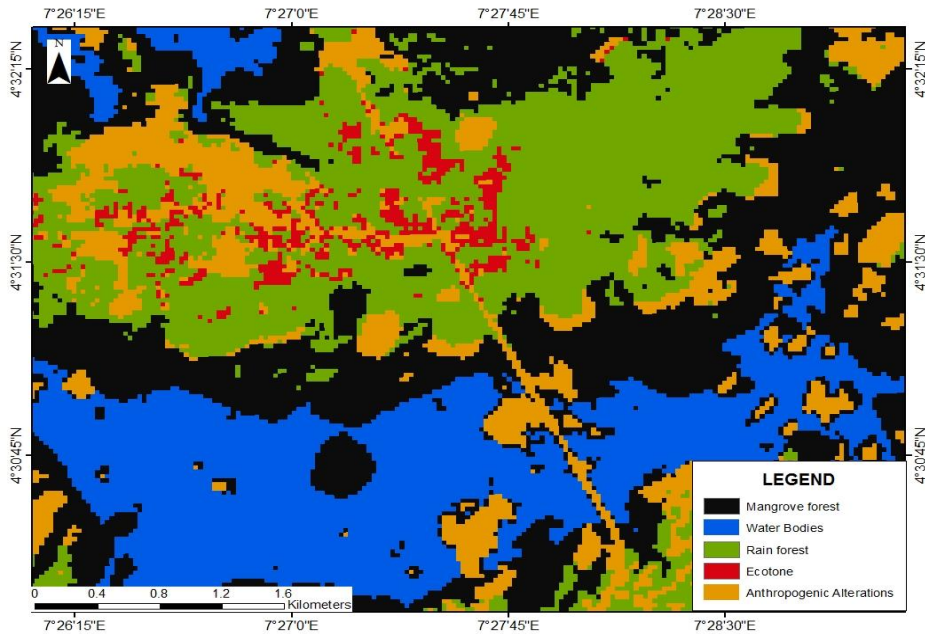


Fig. 5: Satellite imagery of vegetal cover change of the study location site in 2018  
(Source: Landsat 8 (OLI) Images)

### NDVI AND NDBI Analyses

The NDVI and NDBI maps of the study location site for 2018 were generated to reveal the health status of the study location and built-up (anthropogenic) reflection as shown in Figs. 6 and 7, respectively. The greener parts in the NDVI map possess a higher NDVI value showing that the areas are healthy and have vegetal cover. The blue parts of the NDBI maps have high values revealing those areas being influenced and altered by high anthropogenic activities.



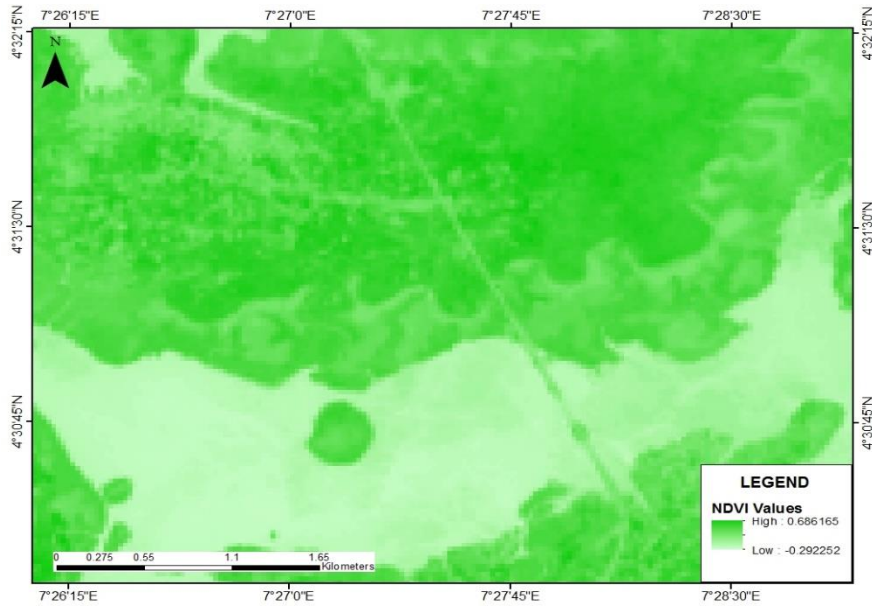


Fig 6: The 2018 Normalised Difference Vegetation Index (NDVI) of the study location. (Source: Landsat 8 (OLI) Images)

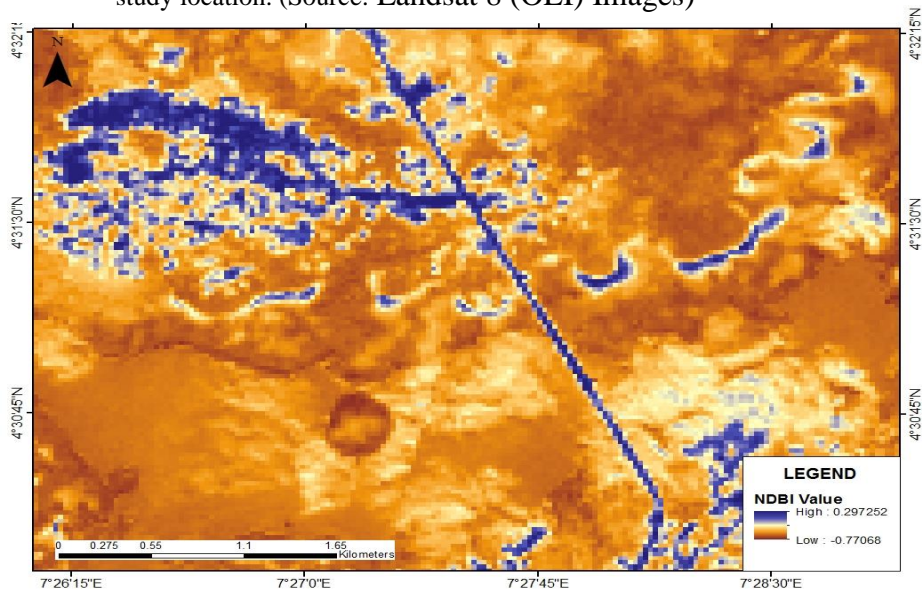


Fig 7: The 2018 Normalised Difference Built-up Index (NDBI) of the study location (Source: Landsat 8 (OLI) Images)



## DISCUSSION

In this study, the three imageries derived from the Satellite (LandSat TM) revealed the extent and varying degrees of vegetal cover changes, loss, depletion and anthropogenic influences over a period of thirty-two years at sixteen 16 - year intervals (1986, 2002 and 2018) at the Asarama study location in Andoni, Rivers State of Nigeria. It also brings to light the importance of satellite geospatial technologies especially GIS and remote sensing in addition to ground trothing. These include giving a holistic view; more information and better interpretation of the past and present by analysing the changes of features and trends, magnitudes and the environmental impacts on the vegetation zones of the study location. This corroborates the reports on the importance of GIS and other geospatial technologies in change detection and analysis (Adefioye, 2013; Ayuyo and Sweta, 2014; Fashae *et al.*, 2017).

Between the periods of 1986 – 2018, the study location (rainforest, mangrove and their associated ecotone) have recorded changes in its vegetation sizes and dimension with a gradual but steady decline of its vegetal covers and bioresources during this period. These changes and losses were primarily due to anthropogenic influences exerted on the vegetation besides the natural intrusions involving climate change, flooding and fires. This corroborates several other studies on the yearly loss of vegetation within the Niger Delta due to same factors (Ayanlade, 2014; Ogboru and Anga, 2015; Ayanlade and Drake, 2017; Izah, 2018; Izah *et al.*, 2018). The anthropogenic activities characterised in this area as revealed by field observation and key informant interview include farming, periwinkle harvesting, logging, bridge/road construction, deforestation, urbanisation and migration due to communal clashes. This agrees with Edwin-Wosu *et al.* (2020) who reported similar human-influenced factors in a study of wetland habitat delineation, floristic ecotype characterisation and ecosystem services of mangal vegetation in Asarama-Andoni marine ecosystem. However, notable vegetal depletion and cover loss around this area started during the onset of the road and bridge construction in the year 1999-2000 as recounted by the key informant; this could probably be the reason for the grave anthropogenic alterations presented in the 2002 satellite imagery which differs greatly from the pristine and undisturbed vegetation of 1986. The road and bridge construction led to increased accessibility to the vegetation ecotype (mangrove, ecotone and rainforest) and their resources by humans which further led to increased anthropogenic alterations as well as reduction in their sizes as revealed by the satellite imagery of 2018. Accessibility to vegetation resources by road creation has been considered as a key factor to vegetal cover loss and depletion (Wachiye *et al.*, 2013).

The 2018 Normalised difference of vegetation index (NDVI) map reveals the present overall health status and the level of anthropogenic impact on the vegetal health of the study location without showing the distinct vegetation types. The greener parts of the NDVI showed that the areas within the study area had vegetal cover while the less green parts were devoid of vegetal cover as a result of anthropogenic alterations and aquatic bodies. The Normalised difference of build-up index (NDBI) map gave an overview of built-up index due to anthropogenic influence across the study location (Asarama) in relation to the extent of vegetal cover without showing the distinct vegetation types. The higher the anthropogenic factors, the higher the reflectance value and bluer the map becomes. This corroborates Akuro (2013) who noted that NDVI and NDBI measure the vegetation health condition and anthropogenic alterations, respectively.

## CONCLUSION

In this study, the use of geospatial technologies especially the GIS was helpful in monitoring and detecting the changing patterns of the various vegetation zones. It measured the extent and pattern of changes in cover conditions over a period of time and gave more than one perspective compared to the use of prehistoric maps and ground trothing measurements. The vegetation zones within the study location have undergone and are undergoing drastic but gradual changes as a consequence of natural and man-made influences or factors. However, most of these factors are due to human/man-induced activities as well as attributes of climate change, flooding, fires, emergence of invasive species (which suppress the growth of indigenous species), industrialisation, urbanisation, migration, pollution, farming, construction of roads, logging, fuelwood harvesting, habitat fragmentation and population increase. All of these have led to the depletion and decline of vegetal cover around the study location which has reduced the floristic composition of these vegetation zones leading to the extinction, endangering and vulnerability

of some critical species. The impacts of vegetal cover loss are already obvious with the unpredictable climate, natural fires and flooding. If appropriate measures are not put in place to preserve the vegetation and its resources, the coming generation will be left with a completely depleted vegetation, lack of bioresources, extreme climate change leading to outbreak and spread of endemic and epidemic diseases, famine, hunger, starvation and even death.

### REFERENCES

- Adefioye, S.A. (2013). Analysis of Land Use/Land Cover pattern along the River Benue channel in Adamawa State, Nigeria. *Academic Journal of Interdisciplinary Studies*, 2(5):95-107.
- Adekunle, A. J. (2006). Conservation of Tree Species Diversity in Tropical Rainforest Ecosystem of South-West Nigeria. *Vegetation Journal of Tropical Forest Science*, 18(2):91–101.
- Ademiluyi, I.A., Okude, A. S. and Akanni, C.O. (2008). An appraisal of land use and land cover mapping in Nigeria. *African Journal of Agricultural Research*, 3(9):581-586.
- Adesina. F.A. and Maduekwe, N. I. (2015). Multi-level Modelling of the Linkages between Vegetation Cover Dynamics and Socio-Economic Factors in the Idemili River Basin of Anambra State, Nigeria. In: *National Colloquium on Frontiers in Environmental Research and Sustainable Environment in 21st Century*. Ibadan University Press, Ibadan, Nigeria.
- Alagoa, E.J. (1999). *The land and people of Rivers State, Central Niger Delta*. Onyema Research publication, Port Harcourt, Rivers State Nigeria.
- Al-Kindi, K.M., Kwan, P., Andrew, N.R. and Welch, M. (2017). Remote sensing and spatial statistical techniques for modelling *Ommatissus lybicus* (Hemiptera: Tropiduchidae) habitat and population densities. *Peer Journal*, 5(12); 1-36.
- Akuro, A. (2016). Trends in Vegetation Cover Changes in Bonny Area of the Niger Delta. *Journal of Applied Science in Environmental Management*, 17(1): 89-103.
- Ayanlade, A. (2014). Remote Sensing of Environmental Change in the Niger Delta, Nigeria. PhD thesis submitted to Department of Geography, School of Social Sciences and Public Policy, King's College, London, University of London.
- Ayanlade, A. and Drake, N. (2016). Forest loss in different ecological zones of the Niger Delta, Nigeria: evidence from remote sensing. *Geo. Journal*, 81(13):717–735.
- Ayanlade, A. and Howard, M.T. (2017). Understanding changes in a Tropical Delta: A multi-method narrative of land use/land cover change in the Niger Delta. *Ecological Modelling*, 364(24):53–65.
- Ayeni, A. O., Kapangaziwiri, E., Soneye, S. O. and Engelbrecht, F. A. (2015). Assessing the impact of global changes on the surface water resources of South-Western Nigeria. *Hydrological Sciences Journal*, 21(3):15-20.
- Ayuyo, I.O. and Sweta, L. (2014). Land Cover and Land Use Mapping and Change Detection of Mau Complex in Kenya Using Geospatial Technology. *International Journal of Science and Research*, 3(3):1-52.

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- Bhatia, S.C. (2006). *Environmental Chemistry*. Satish Kumar Jain for CBS Publishers & Distributors, India.
- Edwin-Wosu, N.L. and Edu, E.A.B. (2013). Eco-Taxonomic assessment of plant species regeneration status in a post-remediated crude oil impacted site in parts of Ibibio-1-oil field in Ikot-Ada Udo, Ikot-Abasi Local Government Area of Akwa-Ibom State, Nigeria. *Asian Journal of Plant Science and Research*, 3(3):14-23.
- Edwin-Wosu, N.L. and Anaele, J. (2018). The Floristic Assessment of Riparian Vegetation Succession in Otamiri River Scape due to Dredging Activity at Chokocho Etche, Rivers State. *Nigerian Journal of Botany*, 31(1):119-143.
- Edwin-Wosu, N. L., Mojuetan, T., Ndukwu, B. C. and Micheal, C. A. (2019). Geospatial Technology, A Satellite -Based Change Detection Agent: Imperative for Analysis And Management of Vegetation Resources in Developing Economy. *Nigerian Journal of Botany*, 32 (1): 25-42.
- Edwin-Wosu, N.L. (2020). Ecological Methods: Bases for Field Exploration Study of Flora Communities. *International Journal of Research and Sustainable Development*, 7(3): 119-139.
- Fashae, O., Olusola, A. and Adedeji, A. (2017). Geospatial Analysis of Changes in Vegetation Cover over Nigeria. *Bulletin of Physical Geography*, 13(1):17-28.
- FGDC (Federal Geographic Data Committee) (2005). *National Vegetation Classification Standard Hierarchy Revisions Working Group*. Federal Geographic Data Committee, Vegetation Subcommittee. Overview July 2005. In: <http://biology.usgs.gov/fgdc.veg>.
- Izah, S.C. (2018). Ecosystem of the Niger Delta region of Nigeria: Potentials and Threats. *Biodiversity International Journal*, 2(4):338-345.
- Izah, S.C. and Seiyaboh, E.I., (2018). Changes in the protected areas of Bayelsa state, Nigeria. *International Journal of Molecular Evolution and Biodiversity*, 8(1):1-11.
- Kuruk, P. (2004). Customary Water Laws and Practices: Nigeria. Available at: <http://www.fao.org/legal/advserv/FOA/UCNCS.Nigeria.pdf> (Accessed: 2/2/21).
- Njike, C. and Daniel, O. (2013). Role of Geospatial Technology in Environmental Sustainability in Nigeria-An overview. *Environment for Sustainability, Abuja, Nigeria, Geospatial Applications - 6555* (Nigeria) TS01D.
- Ogboru, I. and Anga, R.A. (2015). Environmental Degradation and Sustainable Economic Development in Nigeria: A Theoretical Approach. *Journal of Economics*, 3(6):1–13.
- Smith, T.J., Foster, A.M., Tiling-Range, G., Jones, J.W. and Balentine, K.M. (2010). The use of historical charts and photographs in ecosystem restoration: Examples from the Everglades Historical Air Photo Project. Pages 179-191 In: Cowley, D.C. Standring, R.A. and Abicht, M.J. (Eds.), *Landscapes through the lens: aerial photographs and the historic environment*. Occasional Publications of the Aerial Archaeology Research Group, No. 2, Oxbow Books, Oxford, United Kingdom.

NJB, Volume 35 (1), June, 2022 Mojuetan. T. and Edwin-Wosu, N. L.

Twumasi, Y. and Merem, E. (2006). GIS and Remote Sensing Applications in the Assessment of Change within a Coastal Environment in the Niger Delta Region of Nigeria. *International Journal of Environmental Research & Public Health*, 3(1):98-106.

Uluocha, N. and Okeke, I. (2004). Implications of wetland degradation for water resources management: Lessons from Nigeria. *Geo. Journal*, 61(2):151-154.

Upadhyay, M. (2009). *Making GIS work in Forest Management*. Institute of Forestry, Pokhara, Nepal.

Uyigue, E. and Agho, M. (2007). *Coping with Climate Change and Environmental Degradation in the Niger Delta of Southern Nigeria*. Community Research and Development Centre, Nigeria (CREDC).

Wachiye, S.A., Kuria, D.N. and Musiega, D. (2013). GIS-based forest cover change and vulnerability analysis: A case study of the Nandi North Forest zone. *Journal of Geography and Regional Planning*, 6(5):159-171.