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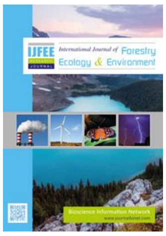

Change detection of the Upper Orashi forest wetland of Nigeria, using geospatial analysis

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ABSTRACT

Wetland is an essential ecosystem that provides numerous goods and services such as tourism and recreation, water purification, and groundwater recharge. It also acts as a carbon sink, which means that it is an essential asset in reducing the level of greenhouse gases in the environment. Despite the value, wetlands are disappearing at a fast rate, however, the need to ascertain the state of Upper Orsahi forest reserve wetland with respect to wetlands change. To ascertain the net and transition change detection in the wetland area of the Upper Orashi Forest Wetland, land cover classification change was performed using Geographic Information Systems and Remote Sensing methods, particularly the supervised classification of land cover data for 2002, 2013, and 2019. The land cover was classified into three classes: wetland, thick vegetation and light vegetation. The result shows a significant degradation of the Upper Orashi forest reserve wetlands within the study period. The data from the questionnaire is to know which sector and activities in the area result in wetland loss. The result shows that industrial sector is the major driver of wetland loss in the area, while the activities include; building of industries, installation of oil and gas facilities, and agriculture. This means that the available laws used to manage Nigeria's wetlands are ineffective. However, there is an urgent need to enact a new regulation for effective/sustainable management of wetlands in the country.

Key Words: *Wetlands, Environment, Niger delta, Vegetation, Class and laws.*

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I. Introduction

Wetlands, characterized by their high water content, can be located in all climate zones over time and play an important role in maintaining ecological balance (Mitsch, 2015). These elements

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(geomorphological, hydrological and biological) work together to create the unique ecosystem we call a wetland. Human activities, the introduction of invasive species and activities causing climate change are only some factors that might alter the type of wetland found in a given area (Liu and Ma, 2002). The ability to manage one's ecosystem and all of the living things in it is the main selling point. Most often, this occurs when the water table is at or near the ground level or when the ground is protected by water (Uluocha and Okeke, 2004). Wetlands were once thought of as transitional habitats or sequential phases between open water and land, but today we recognize them as individual ecosystems with unique ecological features, functions, and values. There is no better indicator of a wetland's ecological health than its bird population or concentration (Robert, 2022). Given the importance of wetland areas, which are particularly rich in biodiversity, excessive usage of wetlands and their resources without understanding their assimilative potential constitutes a fundamental danger to wetland conservation and management.

About half of the world's wetlands disappeared throughout the twentieth century, according to some estimates (Davidson, 2014; UNWWAP, 2003). In the period from 1970 to 2018, the inland and coastal wetlands have declined by about 35% globally (Ramsar Convention on Wetlands, 2018), which is about three times the rate of forest loss globally (Rebelo and Mathew, 2019). This is a devastating blow for those whose income was formerly based on wetland resources. Declining wetland areas in Africa can be attributed to three things: increased human activity, industrialization, and global warming (Rebelo and Mathew, 2019). It is well-documented that human activity has significantly impacted the ecosystems of several lakes, such as Lake Chad and Lake Victoria. According to reports, irrigation using water from Lake Chad has caused a 90% decline in the lake's volume. Increased agricultural activity in the lake's drainage basin has resulted in increased sedimentation and nutrient loading, as well as the introduction of Nile perch, all of which have had significant impacts on Lake Victoria (Rebelo and Mathew, 2019; Verschuren et al., 2002). The types of wetlands present, their precise locations, and the total acreage required for functional wetland management are just some details that may be gleaned from a thorough inventory. Despite their importance, at least 65 percent of African countries lack a comprehensive inventory of their wetlands (Rebelo and Mathew, 2019). Access to or the acquisition of data from satellite-based sensors, such as Earth observation data and remote sensing, will provide a more optimal answer. Because this can provide crucial data on the condition and other features of African wetlands, which can be incorporated into national inventories.

In order to keep tabs on the health of the wetlands and ensure they are well protected, it is necessary to have access to the right monitoring equipment. When it comes to evaluating and monitoring temporal patterns of natural landscapes and environments, remote sensing is an invaluable tool or piece of software. This is because it provides a wide range of data with a notably high temporal resolution (Orimoloye et al., 2018), making it accessible to a wide variety of users (Armand, 2020). Over the past two decades, numerous systems and tools for collecting and analyzing remotely sensed data for the purpose of detecting changes have been established and made available. However, quantitative and qualitative land cover change is assessed by using remote sensing data. Inventorying resources, keeping tabs on wetland areas, and tracking land-use shifts over time are all significantly aided by remote sensing (satellite) (Satish et al., 2017). Researchers are using "Landsat Imageries" as a foundation for multi-temporal analyses of land-surface and satellite data in order to monitor crucial aspects of biodiversity and surface properties, map land cover patterns, and investigate or investigate changes (Adefisan et al., 2015; Onamuti et al., 2017; Hemba and Orimoloye, 2017) [19–21]. As time goes on, the natural landscape, natural resources, the effects of climate change, and the difficulties of protecting biological diversity are seen as increasingly insurmountable (Orimoloye et al., 2018; Hirsch et al., 2011). Wetland deterioration, animal and plant extinctions, habitat transformation and natural landscape monitoring all call for convincing action to preserve them (Waldron et al., 2017; Naeem et al., 2016).

Based on estimates of wetland degradation in the Upper Orashi forest reserve, this report aims to help guide policies to protect these vital ecosystems. This research aims to track any shifts in the wetland at Upper Orashi forest reserve, determine what causes are most at play in this location and assess how well Nigeria's current wetlands management rules are working. This work used an integrated approach, which is uncommon in the field; the results will force policymakers in Nigeria to think hard about protecting the country's valuable wetland ecosystems.

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II. Materials and Methods

Study Area

Upper Orashi Forest Reserve is one of the two Ramsar sites in the Niger-Delta region and eleven Ramsar sites in Nigeria (Edo and Albrecht, 2021). The Upper Orashi Forest Reserve is located in central Niger-Delta, west of the Nun Branch, and south of the section of Nigeria's 'East-West Road' linking Ahoada, Rivers State, 04°53'N 006°30'E and Yenagoa, Bayelsa State (Ramsar, 2008), in Niger-Delta of Nigeria as shown in figure 01. It rests in an area bounded by the Bayelsa State border to the west and the Orashi River to the north and east (Elias, 2016). The northern and southern halves of the Reserve are, respectively, in the Ahoada West and the Abua-Odual) Local Government Areas of Rivers State as shown in figure 02. It is within the Freshwater Swamp Forest (Ramsar, 2007). The site covers a total area of 25,165 hectares (Ramsar, 2008).

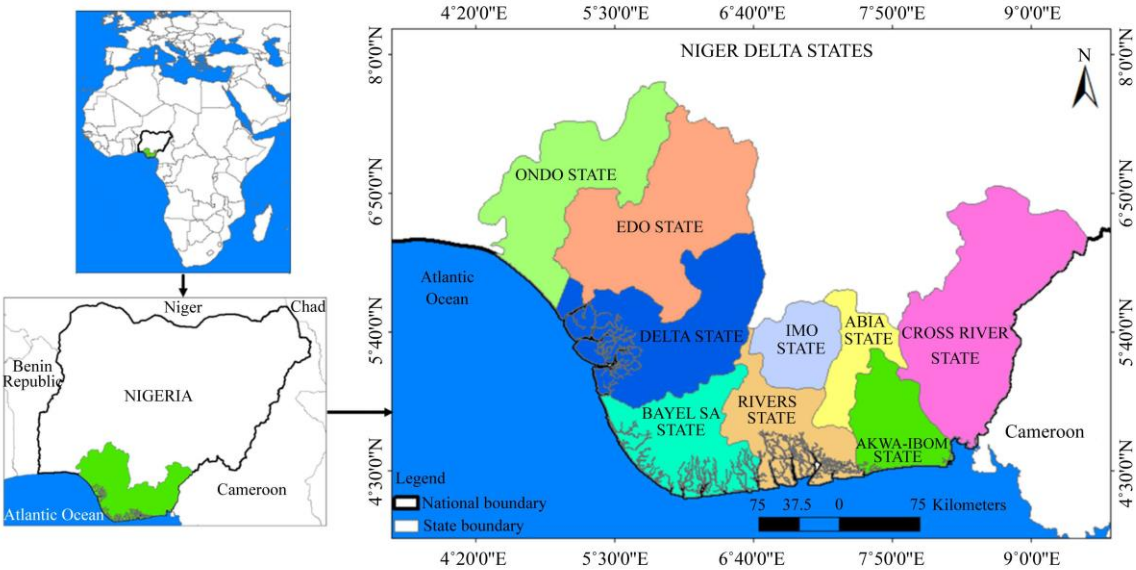

Figure 01. The location of Niger Delta in the southern part of Nigeria. Source: (Edo and Albrecht 2021)

Data collection and analysis

Satellite images captured in 2019, 2008 and 2002 by LANDSAT 8 and 7 were collected from the United States Geological Survey (USGS) Earth Explorer service (United States Geological Surveys, 2019). The three scenes were from the same season and were under similar hydrological conditions. The spatial resolution of the satellite images is 30m. While analyzing the satellite, spatial analysis was performed using ArcGIS version 10.7, including a supervised classification with a maximum likelihood algorithm (Tso and Mather, 2009; Campbell and Wynne, 2011; Lu et al., 2011; Enoguanbhor et al., 2019; Enoguanbhor et al., 2020]. Supervised classification is a process whereby carefully selected samples of pixels in a satellite image are used to assign information classes to unknown pixels (Enoguanbhor et al., 2019, Campbell and Wynne, 2011)

The maximum likelihood algorithm is a classifier that assigns pixels to the class with the highest probability from different pixels that belong to different classes (Enoguanbhor et al., 2019; Lu et al., 2011). The Normalize Difference Vegetation Index (NDVI) was analyzed to identify various pixels with different vegetation values and generate training samples for the classification (Jiang et al., 2021; Kwan et al., 2020). The NDVI is expressed as:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{R}}{\mathrm{NIR} + \mathrm{R}}$$

Where, NIR and R denote near-infrared band and red band respectively.

The land cover types were classified into wetland, light vegetation, and thick vegetation. Accuracy assessments were performed to validate the land cover maps using simple random sampling of 400 points and the composite satellite images as referenced data. The user accuracy (UA), producer accuracy (PA) and over accuracy (OA) for land cover types were assessed (Enoguanbhor et al., 2019). Table 01 shows the outcome of the accuracy assessments.

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Table 01. Accuracy assessments

Land cover types	2019			2008			2002		
	UA	PA	OA	UA	PA	OA	UA	PA	OA
Wetland	87.0%	85.8%		86.0%	87.9%		85.0%	88.3%	
Light vegetation	86.0%	91.3%	90.5%	85.4%	88.8%	89.6%	84.0%	87.4%	89.0%
Thick vegetation	88.2%	89.7%		85.9%	89.2%		86.7%	89.8%	

Additionally, questionnaires were designed, distributed and retrieved to identify the driving factors of wetlands degradation. The questionnaires were to professionals in the (Federal/State Ministry of Environment, Environmental NGOs, NDDC, and Lecturers/Ph.D Students). A total of 162 questionnaires were distributed and 152 were retrieved. Convenience sampling method, which is a non-probability sampling (Rebecca, 2014) that involves the use of conveniently available respondents to be part of the process (Thomas and David, 2017; Ilker et al., 2016), was used to select the respondents. However, this process does not require a specific pattern (Galloway, 2005) but ensured that the participant belongs to one of the targeted groups.

III. Results

The results indicate that wetland cover of the Upper Orashi forest in 2002 was 30.83 km^2 but decreased to 15.70 km^2 in 2008 and 5.81 km^2 in 2019 (Table 02). Light vegetation class in 2002 covered an area of 162.90 km^2 but increased to 178.90 km^2 in 2008 and 169.57 km^2 in 2019 (Figure 03). While the thick vegetation covered an area of 66.88 km^2 in 2002, it covered 66.28 km^2 in 2008 and 85.23 km^2 in 2019. To know the percent change of the land cover as classified, excel was used and the result shows that in 2002 wetland area was 11%, in 2008, it was 7% and in 2019, it was 3%. For thick vegetation, in 2002, it was 27%. In 2008, it was 26% and in 2019, it was 33%. While light vegetation in 2002 was 63%, in 2008, it was 69% and in 2019, it was 65% (Figure 03).

Table 02. Land cover/wetlands ecosystem dynamics for Upper Orashi forest reserved for 2002, 2008 and 2019

Land cover classes	2002	2008	2019
	Area km^2	Area km^2	Area km^2
Wetland	30.83	15.70	5.81
Light vegetation	162.90	178.90	169.57
Thick vegetation	66.88	66.28	85.23
Total	**260.61**	**260.88**	**260.61**

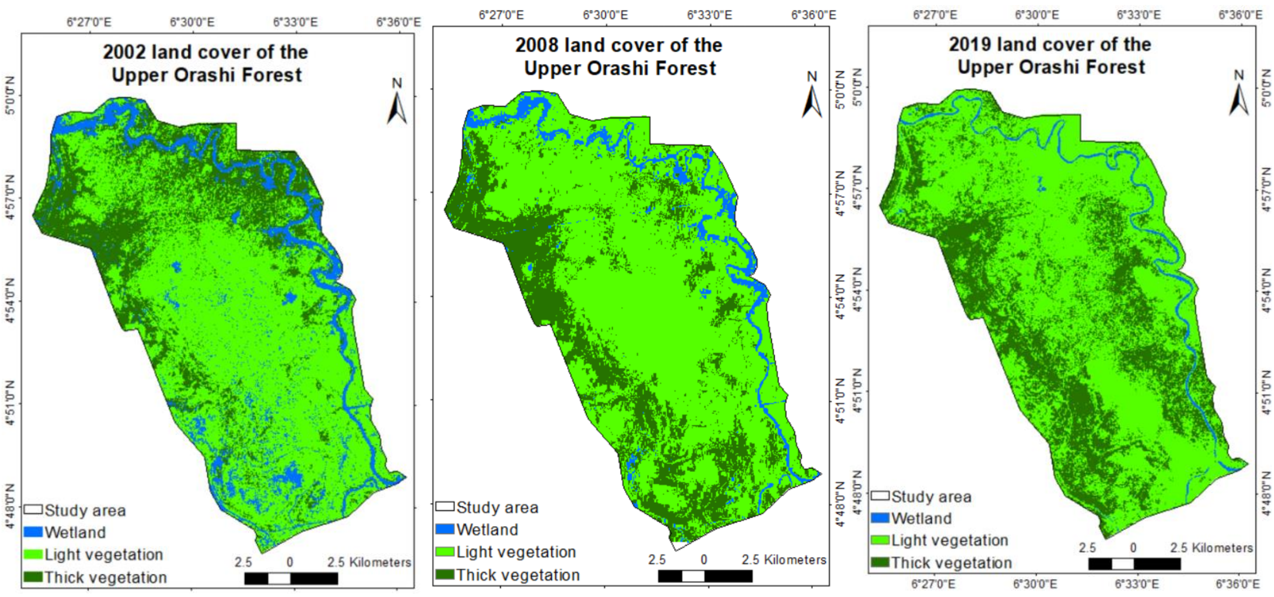

Figure 02. Shows the map of landcover change for 2002, 2008 and 2019

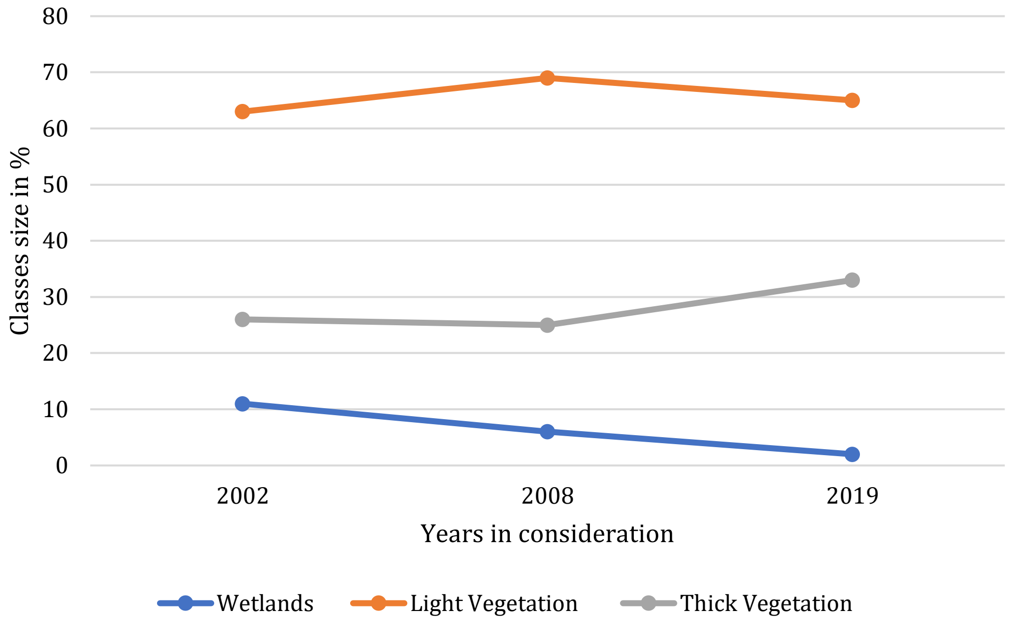

Figure 03. Shows the percentage of land cover change

For wetland, there is consistent decrease; in light vegetation it shows an increase between 2002 to 2008 from 162.90 km² in 2002 to 178.90 km² in 2008 and decreases in 2019 to 169.75 km². Thick vegetation decreased between 2002 to 2008 and increased in 2019 as follows 66.88 km², 66.28 km², and 85.23 km². However, the result shows a relationship or interdependence in both light and think vegetation because an increase in light vegetation resulted in a decrease in thick vegetation, and a decrease in light vegetation resulted in an increase in thick vegetation (Table 03).

Table 03. Change detection between 2002 – 2008 and 2008 – 2019

Land Cover Class	Areas in km²	Wetlands	Light vegetation	Thick vegetation
2008 -2002	Km²	-15.13	16.00	-0.6
2019 - 2008	Km²	-9.89	-9.33	18.95
Total	**Km²**	**-25.02**	**6.67**	**18.35**

On average, the wetland of the Upper Orashi forest between 2002 to 2008 is -2.52 km² and from 2008 to 2019, is -0.9 km². The average change of light vegetation between 2002 to 2008 is 2.67 km² and 2008 to 2019 is -0.85 km². While the average change of think vegetation between 2002 to 2008 is -0.1 km², that of 2008 to 2019 is 1.72 km².

Table 04. Average change in the rate of wetland and other classified vegetation in km²

Land Cover Class.	Wetland	Light Vegetation	Thick Vegetation
2002 - 2008	-2.52	2.67	-0.1
2008 - 2019	-0.9	-0.85	1.72

To identify the driving factors of wetlands degradation, the questionnaire analysis shows that 10.5% of the respondents attributed the drivers to industrial factors. In comparison, 2.63% attributed the factors to anthropogenic factors, 81.58% to both industrial and anthropogenic factors, 2.63% to others and 2.63% didn't respond to this question. Respondents' opinion that wetland degradation is a result of (A) agricultural purpose (5.26%), (B) Infrastructural developments (roads and houses contraction) (2.63%), (C) Building of industries (5.26%), while none of the respondents believes that only installation of oil and gas facilities are resulting to wetland loss in the study area (D), and the same for option (E) dredging. 5.26 percent of respondents ascribed drivers to options A and B, 9.21 percent credited drivers to options A and D, 1.32 percent of respondents attributed drivers to options B and C, and 10.53 percent attributed drivers to options B and D. While 2.63% ascribed the driver to option B and E, 1.32% opined for option B and F, 2.63% of the respondents opined for option B and F, 2.63% credited the drivers to option D and E, and 2.63% of the respondents opined for option A and B and C. While 5.26% of respondents attribute the drivers to options A and B and D, 15.79% of respondents

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attributed the drivers to options A and C and D, 5.26% of respondents attributed the drivers to options B and C and D, 6.58% of respondents attributed the drivers to options A, B, and C, and 1.32% attributed the drivers to options B and C and D and E. 2.63% of respondents chose options A, B, C, D, and E, while 2.63% did not respond to this question.

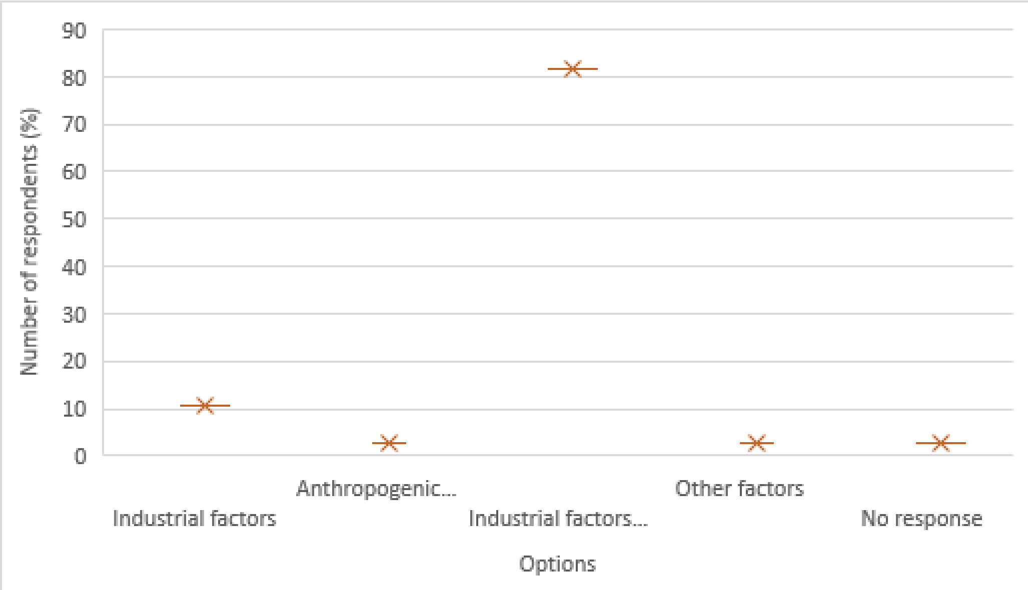

Figure 04. Shows the types of factors that result in wetland reduction/disappearance in the region

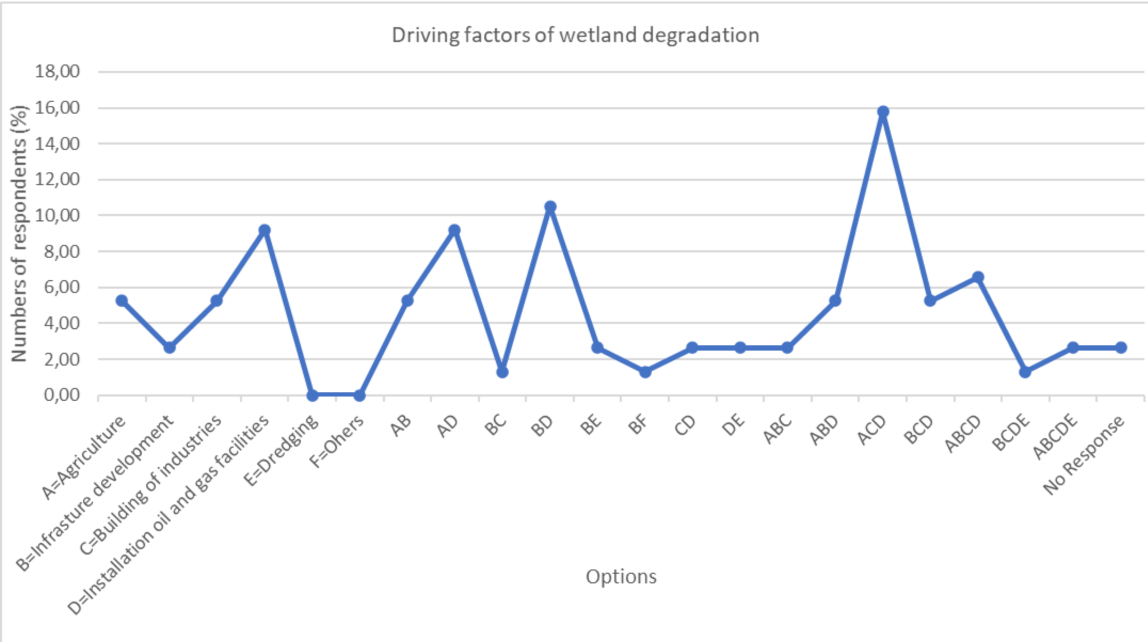

Figure 05. Shows activities that result in wetland degradation in Upper Orashi Forest Reserve Wetland

IV. Discussion

The results show an incessant wetland loss in the study area within the study period, with the Upper Orashi forest covering an area of 30.83 km^2 in 2002, 15.70 km^2 in 2008, and 5.81 km^2 in 2019. This implies that the present wetland management program in Nigeria is not actualizing its goals. Nigeria as a country does not have a specific framework for the management of wetlands but only uses the general environmental laws/policies, which include; the National Oil Spill Detection and Response Agency Act 2006 (NOSDRA), National Oil Spill Detection and Response Agency Act 2006 (NOSDRA) and the EIA Act. for the management of wetland (Edo and Albrecht, 2021). For this reason, there is a need to review the laws used for the management of wetlands in Nigeria. A similar observation was

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made for wetlands in Sanjiang plain in China by (Song et al., 2014), LULC in the Sanjiang plain was most noticeable in the wetland area; the rapid loss of wetland area in Sanjiang plain is as a result of the conversion of wetland area into cropland (Fengqin et al., 2017). According to European Commission, in the 20th century, Europe was reported to have lost about two-thirds of its wetland (European Commission, 2007), which led to a considerable decline in the size, number and quality of wetlands and their related areas.

The main driving factors of wetlands in Upper Orashi forest reserved are agriculture, oil and gas installations and building of industries, as shown in Figure 04 and Figure 05. Agriculture and urbanization are driving factors in China's wetlands (Weihua et al., 2019). Other drivers of wetland change include population growth and economic development (infrastructural development, introduction and spread of invasive species, and overfishing). Generally, human activities have been known to be draining, converting and infilling wetlands for centuries and still doing so (Milton et al., 2018).

The inability of Nigeria to effectively manage its forests has made it easy and safe for criminals to carry out their nefarious activities. The impact of this unpleasant development cut across the social, economic and environmental domains. Previously, the militants operating in the creeks of Niger-Delta engaged in activities such as kidnapping, hostage-taking, blowing and shutting down of oil installations and illegal oil bunkering. These activities result in environmental degradation and economic sabotage (Nwogwugwu et al., 2012). The insecurity in this region has impacted in the changed vegetation, as shown in Figure 04, as militants have taken over part of the site (creeks) as their hideout place. Between 2002 and 2008, it was observed that human activities were impacting thick vegetation, making it lose its original state (thickness) to light vegetation, due to the intensified crime rate in the area. Knowing that the forest is the hiding place for the militants (Nwogwugwu et al., 2012), the people are restricted from this area, thus, the thick vegetation increased between 2008 to 2019 as the light vegetation developed into thick vegetation.

The result shows that Upper Orashi forest reserve wetland is fast-degrading, considering the fact that Nigeria has no specific framework for managing and conserving wetland. However, it is very important and urgent to review the environmental laws being used for the wetlands or enact a new regulation for effective wetlands, as the laws being used presently is not achieving their goals concerning wetland conservation and protection. It is important to better enact a special law for effective wetland management in Nigeria, in line with the aim of Ramsar Convention in actualizing wetlands conservation or sustainable wetland. The Niger-Delta region is a hotspot for biological diversity with some endemic species, including Sclater's guenon (Cercopithecus sclateri), Nigerian white-throated guenon (Cercopithecus erythrogaster pococki), red-capped mangabey (Cercocebus torquatus) and the endangered Nigeria–Cameroon chimpanzee (Pan troglodytes ellioti) (Izah, 2018; Hilton-Taylor, 2000).

The loss of these important natural ecosystems will result in the loss of some of the endemic and endangered species found within the area (Edo and Albrecht, 2021). Due to the functions/values of wetlands and for effective management of the wetland, the United Nations Environmental Programme (UNEP) in 2012 called for a quick consolidation of the vital role of wetlands in decision making for the need of both present and future protection, restoration of its degraded area and its sustainable use as an essential unit of the change or alteration into a resource-efficient, sustainable world economy. Despite the ecological functions of wetlands, no restoration program or project has been undertaken in Nigeria.

Nigeria has several environmental laws, including; Federal National Park Act, Territorial Waters Act, Land Use Act and the Endangered Species Act. The major challenge of the ineffectiveness of environmental laws in Nigeria has been attributed to the inability to effectively implement and enforce the laws available for the wetland management. To actualize effective management of the environment, Nigeria has signed several international environmental laws like the Convention on Wetlands of International Importance, especially As Waterfowl Habitat, Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and Convention on Biodiversity. Nigeria established National laws for managing its environment, which include the National Oil Spill

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Detection and Response Agency Act 2006 (NOSDRA), National Oil Spill Detection and Response Agency Act 2006 (NOSDRA) (Cane and Kritzer, 2012), Environmental Impact Assessment Act, and Hydrocarbon Oil Refineries Act. The Nigeria's laws available for the management of its environment are of a high standard comparable to that of developed countries, there is a need to evaluate the enactment process and the process for its enforcement. With the consistent degradation occurring in the Upper Orashi Forest Reserve wetland, no individual, group or company has been held responsible or sanctioned because their/its activities are resulting or causing wetland degradation in the area and Nigeria at large. This shows the ineffectiveness of the law being used for wetland management in the country. If this were to be functional, the rate of wetland degradation would have been reduced or stopped.

IV. Conclusion

With the increasing identification of wetlands value in the environment and their ecological functions, there is an urgent need to address the challenges of wetland loss in the area, this research has shown that the Upper Orashi Forest Reserve Wetland is degrading and resulting in biodiversity loss in the area, and these needs urgent attention to conserve and protect this important ecosystem. The increasing rate of wetland degradation in the area can be ascribed to human activities and the inability of government agencies to implement and enforce the available laws for managing and protecting wetlands in Nigeria. To effectively manage and protect wetlands in Nigeria, a strategy must be developed to balance industrial activities, agricultural activities, and environmental protection. This can be done through a more practicable process across an established bargain, usually initiated to allow residents to participate in the execution of the country's developed wetland conservation and protection strategies. To effectively resolve wetlands challenges in Nigeria, several government agencies have to meritoriously harmonize in reinforcing laws and guidelines or regulations being used for wetlands management at local, regional and national scales. Reviewing the policies used for wetland management and considering the driving factors identified by this research, two points of argument have been forwarded. First is reviewing the existing policy available for wetland management, with elements in different sectors. It magnifies the issue of wetland development and encourages the respective institutions to consider the issues of wetland development in their strategic and annual development plans. Secondly is to enact a separate regulation for wetland management. The multi-sectoral interests in wetlands make it imperative to involve several sectors to coordinate their efforts to generate reliable data on the value and other attributes of wetlands to influence policymakers to take appropriate actions. However, EIA should be met to be carried out before undertaking any development capable of affecting wetlands, irrespective of the presence or absence of wetland development policy or strategy.

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