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ANALYSIS OF OYAN RIVER CHANNEL CHANGES USING REMOTE SENSING TECHNOLOGY

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Abstract

This study employs remote sensing technology to analyze river channel changes in Oyan River, Abeokuta North, Ogun State, Nigeria. Understanding and monitoring river dynamics are essential for ecological sustainability and effective water resource management. Remote sensing and GIS techniques provide a cost-effective and efficient approach to assessing these changes. Landsat satellite images (30m resolution) from 2002 to 2023 at three-year intervals were compared and analyzed. Land use land cover, river channel, and river bank erosion maps were produced. The quantity of accretion and erosion was assessed using the geoprocessing tool in a GIS system. The results of this study revealed significant morphological changes in the Oyan River channel. Between 2002 and 2011, erosion and accretion affected 95 and 104 hectares, respectively, while 2403 hectares remained unchanged. From 2011 to 2023, erosion and accretion increased to 213 hectares each, with 2294 hectares unchanged. Over the entire study period (2002–2023), 147 hectares underwent erosion, 156 hectares experienced accretion, and 2351 hectares remained stable. A critical period of accelerated erosion occurred between 2011 and 2023, largely influenced by the 2014 flood event, which significantly altered the river's course. These findings highlight the urgent need for effective management strategies to mitigate flood risks and protect surrounding communities and infrastructure, ensuring the sustainable use of river resources.

Keywords - River Channel, Erosion, Accretion, Remote sensing, Oyan River

1.0 INTRODUCTION

A river is a dynamic, self-sustaining natural watercourse that flows progressively towards an ocean, sea, or another river, typically comprising freshwater and supporting diverse aquatic ecosystems [6]. River channels are dynamic natural systems that are constantly changing due to various natural and anthropogenic factors. Understanding these changes is crucial for environmental management, flood prevention, urban planning, and ecological conservation. The advancement of remote sensing technology has revolutionized the way we monitor and analyze river channel dynamics. Remote sensing provides high-resolution, time-series imagery that enables detailed and accurate analysis of spatial and temporal changes in river channels [4]. River systems are among Earth's most dynamic and complex landscapes, playing a crucial role in shaping the terrestrial environment. These systems serve as vital water sources, support rich biodiversity, and provide numerous ecosystem services, including transportation, irrigation, and recreation. However, river channels are constantly evolving due to natural processes and human activities. This dynamic nature makes them a subject of extensive study in the fields of geomorphology, hydrology, and environmental science [5].

Historically, the study of river channels has involved direct field observations and manual surveying techniques. Early geomorphologists like William Morris Davis and Luna Leopold laid the groundwork for understanding river channel morphology and dynamics. Their pioneering work provided insights into how rivers sculpt landscapes, transport sediments, and respond to climatic and geological changes. However, traditional field-based methods were limited in spatial coverage and temporal resolution, making it challenging to capture the full complexity of riverine environments [10]. The advent of remote sensing technology has revolutionized the study of river channels. Remote sensing involves the acquisition of information about the Earth's surface without direct contact, typically through satellite or aerial imagery. This technology offers several advantages over traditional methods, including extensive spatial coverage, frequent temporal updates, and the ability to access remote or hazardous areas [1]. With the launch of the first Earth-observing satellites in the 1960s, such as Landsat, scientists gained unprecedented access to high-resolution imagery of the Earth's surface. These images provided detailed information on land cover, vegetation, and hydrological features, enabling more comprehensive analyses of river systems. Over the decades, advancements in remote sensing technology, including higher resolution sensors, multispectral and hyperspectral imaging, and improved data processing techniques, have further enhanced our ability to monitor and analyze river channels [4].

Despite these technological advancements, several challenges remain in the analysis of river channel changes using remote sensing. One major challenge is the processing and interpretation of large volumes of remote sensing data. This requires sophisticated algorithms and computational tools to extract meaningful information from raw images. Additionally, the accuracy of remote sensing analyses depends on the quality and resolution of the imagery, which can be affected by factors such as cloud cover, sensor limitations, and data availability [2]. The integration of remote sensing with geographic information systems (GIS) allows for the comprehensive analysis and visualization of river channel changes. This approach provides valuable insights into the patterns and processes of river morphology, sediment transport, and channel migration [7]. The integration of remote sensing data with Geographic Information Systems (GIS) has opened new avenues for spatial analysis and visualization. GIS is a powerful tool that allows researchers to store,

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manipulate, and analyze spatial data. By combining remote sensing imagery with GIS, researchers can create detailed maps, model spatial relationships, and analyze temporal changes in river channels with greater accuracy and efficiency [8]. This integration has facilitated numerous applications, such as detecting changes in river course, assessing sediment transport and deposition patterns, and evaluating the impacts of human activities like dam construction, land use changes, and urbanization on river dynamics. For instance, studies have shown how deforestation and urban sprawl can alter hydrological cycles, increase runoff, and accelerate riverbank erosion, leading to significant changes in river morphology.

River channel changes pose significant threats to ecosystems, infrastructure, and human settlements worldwide. In Nigeria, particularly, river channel dynamics impact agriculture, water resources, and urban development. The Oyan River, located in Ogun State, is crucial for irrigation, fishing, and drinking water supply for surrounding communities. However, increased human activities and climate variability have altered its channel morphology. Given the dynamic nature of the Oyan River and the impact of human activities on it, there is a critical need for continuous monitoring and analysis. Understanding these changes is crucial for effective river management and sustainable development.

This study employs remote sensing technology to analyze river channel changes in the Oyan River between 2002 and 2023. Leveraging multi-temporal Landsat satellite images, this research investigates spatial and temporal variations in river width, course, and erosion and evaluates the effectiveness of remote sensing technology for monitoring river channel changes. The findings will provide valuable insights into the erosion and accretion patterns of the river channel dynamics as well as contribute to the understanding of river channel changes in Nigeria and inform evidence-based decision-making for sustainable river management. By leveraging remote sensing and GIS technologies, this research can contribute to a deeper understanding of river channel dynamics and support sustainable river management practices. This research aligns with the mission of advancing the science and technology of spatial data management [3]. The analysis of river channel changes using remote sensing images represents a critical area of research with significant implications for environmental management, flood prevention, urban planning, and conservation.

2.0 THE STUDY AREA

The study is Oyan River. The Oyan River is a significant watercourse located in Ogun State, southwestern Nigeria within 7°15'30" N and 3°15'20" E. It is a tributary of the Ogun River and plays a vital role in the region's hydrology. The river is in the savannah region, with sparse trees and grasses and low fertility. It covers 4,000 hectares and has a catchment area of 9,000 km^2. The river supplies water to Lagos and Abeokuta and supports the 3,000-hectare Lower Ogun Irrigation Project. Historically, the Oyan River has undergone significant changes influenced by both natural factors and human interventions [9]. The study area map is shown in Figure 1.

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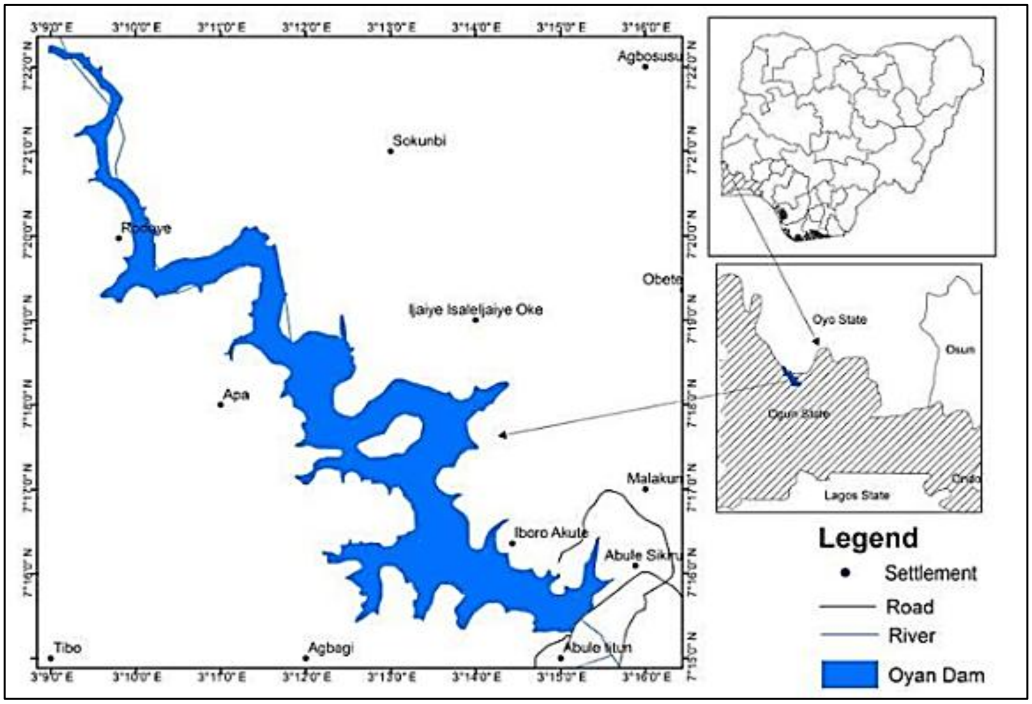

Figure 1: Map Showing the Oyan River

3.0 MATERIALS AND METHOD

3.1. Materials

The study utilizes Landsat satellite images with a 30m resolution, specifically Landsat TM 5 and Landsat 8 OLI/TIRS, acquired for the years 2002, 2011, and 2023. These images were sourced from the United States Geological Survey (USGS) Earth Explorer platform. Additional materials include topographic maps, GIS software (ArcGIS and QGIS), and remote sensing tools used for image processing and analysis.

3.2. Method

The study makes use of remote sensing images obtained from the United States Geological Survey (USGS) Agency (https://www.usgs.gov/) Earth Explorer database. The specific datasets used include Landsat 5 TM images for the years 2002 and 2011, and a Landsat 8 OLI image for the year 2023. Additionally, a shapefile for the study area was created using Google Earth Pro to define the boundaries of the Oyan River study area. The Landsat images have a spatial resolution of 30 meters, suitable for medium-scale analysis of river channel changes. The selection criteria for the images included availability, cloud cover, and seasonality, ensuring optimal conditions for

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analyzing river channel dynamics. The 2002 image represents baseline conditions, while the 2011 and 2023 images enable the assessment of changes over 21 years.

Google Earth Pro was employed to delineate the Oyan River basin. The delineation process involved visual interpretation using satellite imagery and topographic maps, identification of river channel boundaries and adjacent land cover features, manual digitization using Google Earth Pro's polygon tool, and shapefile generation to define the Oyan River basin. This shapefile was used to extract the relevant remote sensing data, ensuring accurate spatial referencing and analysis.

3.3. Data Processing

The raw data underwent several preprocessing steps to ensure it was suitable for analysis, including cloud cover assessment (selected at 20% for the Landsat images downloaded), and radiometric and atmospheric corrections to enhance image quality and accuracy.

Image processing and classification were carried out. The Landsat TM 5 and Landsat 8 OLI/TIRS images were preprocessed by layer-stacking bands 4, 2, and 3 (blue, red, and green) to create a true-color composite. To ensure geometric and radiometric consistency, the images were projected onto the Universal Traverse Mercator (UTM) Zone 31 N coordinate system, utilizing the World Geodetic System (WGS) 1984 datum. Subsequent radiometric correction involved converting digital numbers (DN) to top-of-atmosphere reflectance values. Unsupervised classification was then applied to extract water body maps of the Oyan River study area for the specified study periods.

3.4 River bank erosion mapping

To analyze changes in the Oyan River's channel, raster images from 2002, 2011, and 2023 were converted to polygon format using ArcGIS's raster-to-polygon method. This established the study area's location of interest. A new data frame was created to categorize research periods: 2002-2011, 2011-2023, and 2002-2023. The categorized images were then layered and intersected using ArcGIS geoprocessing tools to identify temporal changes in the river channel. Finally, GIS mapping highlighted the spatial changes in the study area over the three periods.

3.5. River channel change detection

The research region's river dynamics were assessed using advanced remote sensing data from Google Images and Landsat satellites. GIS-based vectorization facilitated the identification of river shifting, characterized by deviations from the river's baseline course. A multi-faceted approach, integrating remote sensing data, field observations, mapping calculations, and thematic base mapping with quantitative data creation.

4.0 RESULTS AND DISCUSSION

4.1 Land Use Land Cover Maps

Land Use Land Cover (LULC) maps of the Oyan River were created for the years 2002, 2011, and 2023. These maps were instrumental in identifying and analyzing changes in the river channel over the specified periods. The LULC maps for 2002, 2011, and 2023 respectively are shown in Figures 4a, 4b, and 4c.

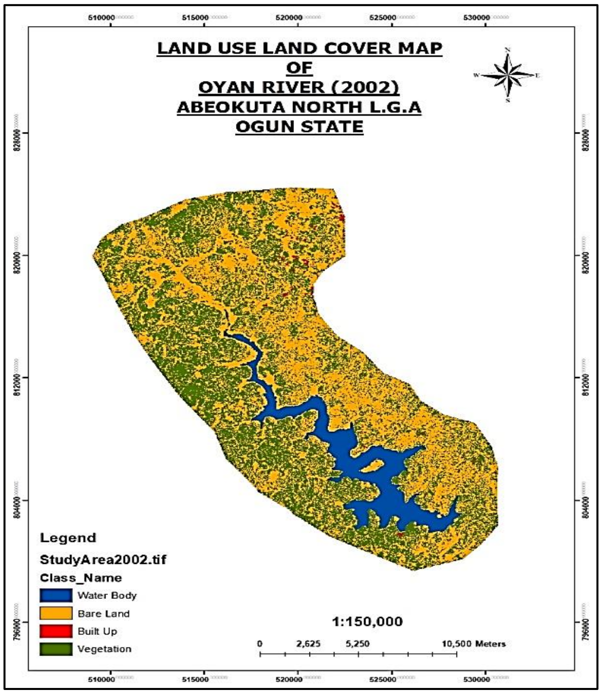

Figure 4a: Land Use Land Cover Map (2002)

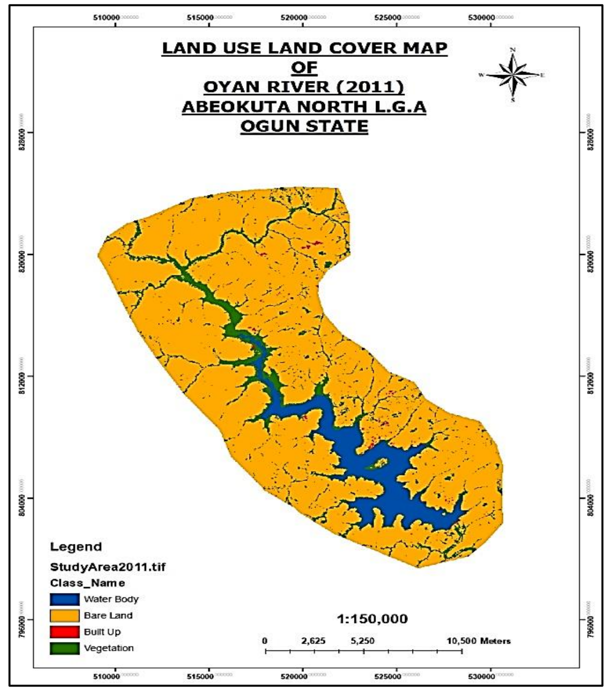

Figure 4b: Land Use Land Cover Map (2011)

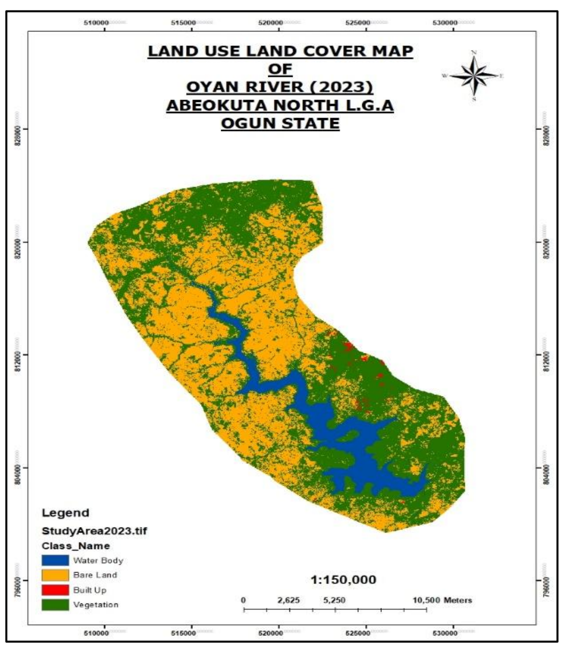

Figure 4c: Land Use Land Cover Map of Oyan River (2023)

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In the 2002 LULC map, the river channels are clearly defined and prominent, with water bodies marked in blue indicating the flow and extent of the Oyan River. The river appears to have a substantial width, suggesting a stable and well-maintained flow. The surrounding areas are predominantly covered with vegetation (green) and bare land (yellow), which likely contribute to natural filtration and minimal sedimentation in the river, promoting a healthy river flow. In 2011, the LULC map shows some changes in the river channel flow. The water bodies (blue) remain visible, but there appears to be a reduction in vegetation (green) and an increase in bare land (yellow). The decrease in vegetation could lead to increased sedimentation and runoff into the river, potentially affecting the flow and quality of the river water. Additionally, the slight increase in built-up areas (red) near the river could introduce pollutants and further disrupt the natural flow of the river. In the 2023 LULC map, the river channels continue to be well-defined, and there is a noticeable increase in vegetation (green) around the river. This resurgence in vegetation cover suggests improved conservation efforts or natural regrowth, which can enhance the river flow by reducing sedimentation and promoting groundwater recharge. The built-up areas (red) have further expanded, particularly near the river, which could pose challenges such as increased runoff and potential pollution. However, the overall increase in vegetation is a positive sign for the river's health, indicating a potential improvement in water quality and flow stability.

4.2 River Channel Maps

The map of the flow pattern (River Channel) of the river was created for each year in view. The overlayed River Channel map was also created. The river channel maps for 2002, 2011, and 2023 respectively are shown in Figures 4d, 4e, and 4f, and the overlaid map in Figure 4g.

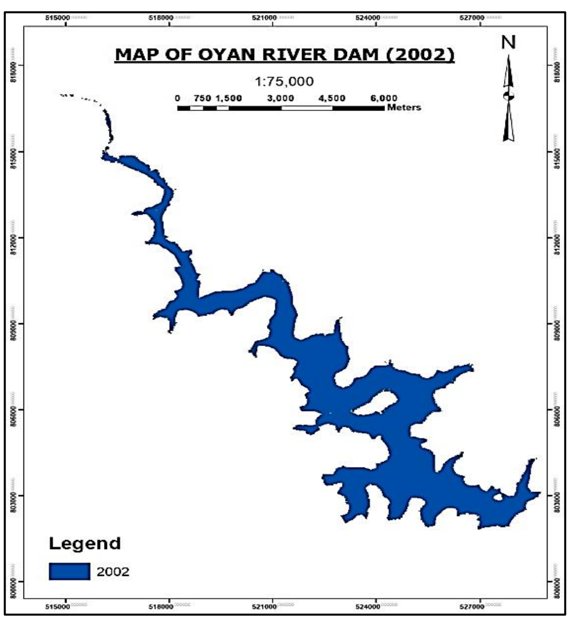

Figure 4d: River Channel Map of Oyan River (2002)

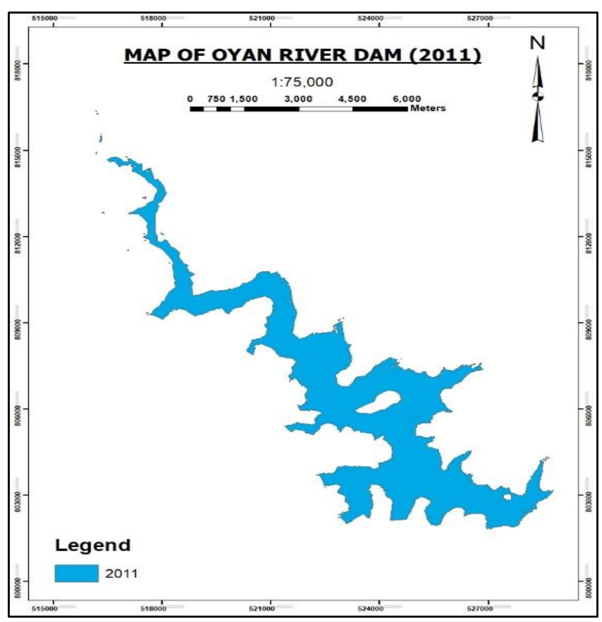

Figure 4e: River Channel Map of Oyan River (2011)

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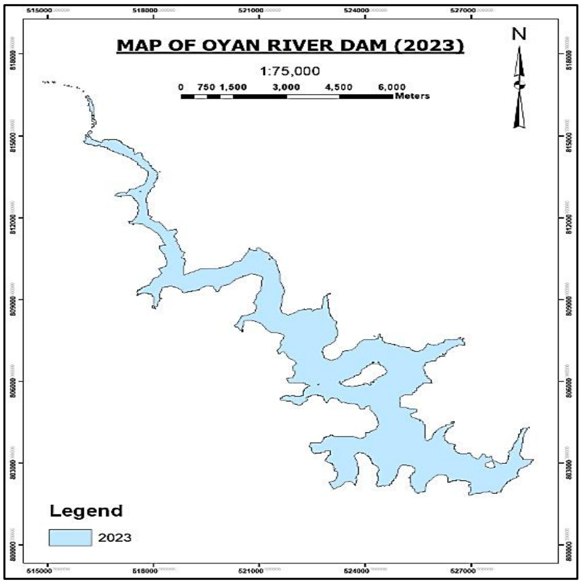

Figure 4f: River Channel Map of Oyan River (2023)

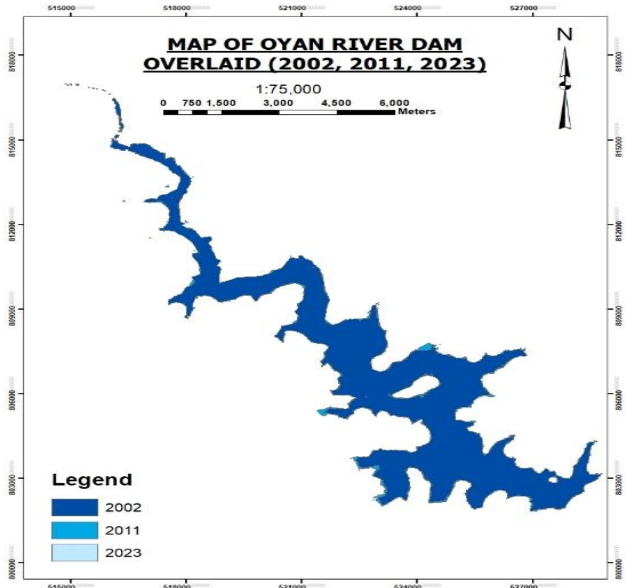

Figure 4g: River Channel Map of Oyan River (2002-2023)

The river channels of each year seemed familiar from 2002 to 2023, by displaying a relatively similar pattern. The overlaid river channel map (Figure 3d) exposes the insignificant diversity recorded in the river channels of each year, having the channel in 2002 and 2023 almost regularly flown, with a slight difference in the 2011 flow channel.

4.3 River Bank Erosion Maps

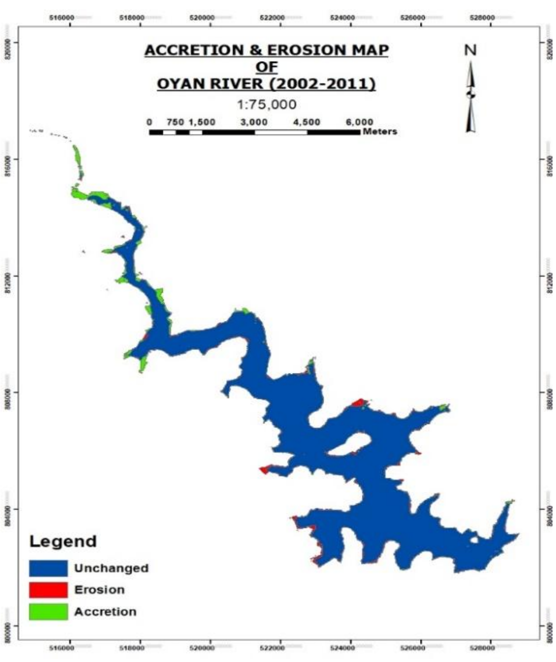

Figure 4h: (2002 2011)

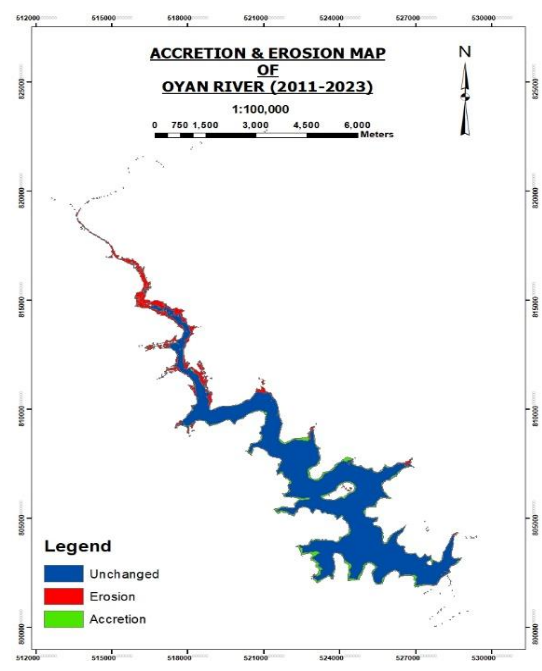

Figure 4i: (2011-2023)

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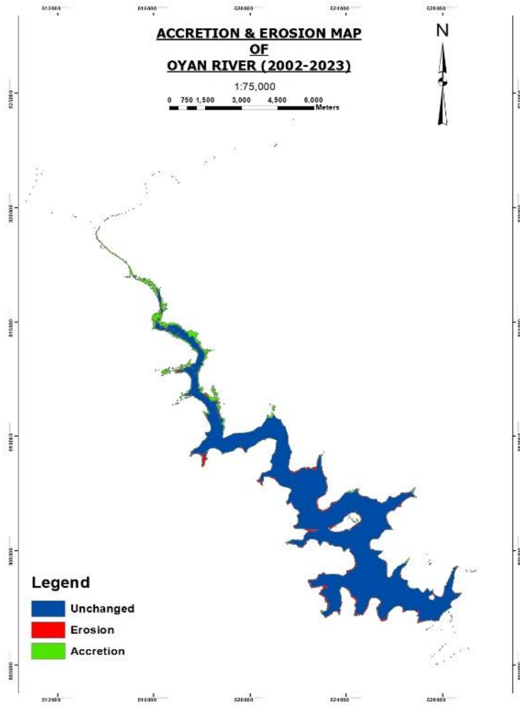

Figure 4j: Accretion and erosion map of Oyan River (2002-2023)

The river bank erosion maps for each of the years in comparison are shown in Figures 4h, 4i, and 4j.

4.4 Accretion and Erosion Maps

The study revealed changes in the river channel morphology over the study period. Figures 4a, 4b, and 4c describe the accretion and erosion pattern of the river, and the following were recorded:

•**2002-2011:** The River exhibited noticeable changes in its course, with sections showing increased accretion with 104 hectares of land covered. The width of the river in some parts expanded due to erosion, which covered approximately 95 hectares of land, while other areas experienced sediment deposition, leading to narrowing. Some significant (2403 hectares) parts of the river channel remained unchanged. This if not well managed can lead to substantial loss of land, potentially affecting agricultural areas, forests, or wildlife habitats which can result in significant economic losses, particularly in areas with agricultural or recreational activities. Eroded sediment can lead to increased sedimentation downstream, potentially clogging waterways, damaging infrastructure, and altering ecosystems. Furthermore, Channel erosion can increase flood risk by altering the river's flow, potentially leading to more frequent or severe flooding. Also, accretion can lead to increased sedimentation, which can degrade the water quality, it can also affect the distribution of pollutants, potentially leading to higher concentrations in certain areas. Accretion can also change the flow dynamics of the river, thereby affecting the sediment transport and deposition patterns, and impacting the downstream ecosystem. These implications highlight the importance of addressing erosion in river channel change detection analysis to mitigate potential negative consequences.

•**2011-2023**: In a river channel change detection analysis, observing 213 hectares of both accretion and erosion, while the overall area remains unchanged at 2294 hectares, indicates a dynamic equilibrium with significant implications. Accretion fosters new land formation, enhancing habitats for certain flora and fauna but potentially encroaching on aquatic habitats. Conversely, erosion results in habitat loss increased downstream sedimentation, and possible negative impacts on water quality. Hydrologically, these changes can alter river flow dynamics, affecting flood risks, navigability, and water distribution. Biodiversity is also impacted, as accretion creates new habitats and erosion destroys existing ones, affecting species dependent on these environments. Erosion can lead to the loss of fertile agricultural land, impacting local agriculture and causing economic losses for farming communities. Both accretion and erosion threaten infrastructure such as roads, bridges, and buildings, with erosion undermining foundations and accretion leading to land encroachment. These landscape changes also influence land use planning and property values, with erosion reducing available land for development and accretion creating new land that could be utilized or contested. The stable overall area suggests a balance between accretion and erosion, leading to shifting river channels and affecting long-term river morphology. Continuous sediment changes impact the stability of riverbanks and the channel itself, making future changes unpredictable and complicating long-term planning and management. Policy and management strategies must account for this balance to ensure effective river management. Understanding the interplay of accretion and erosion informs sediment management practices, flood control measures, and habitat restoration projects. Targeted conservation efforts can protect vulnerable ecosystems and manage sediment loads effectively.

•**2002-2023**: In the context of river channel change detection, observing 156 hectares of accretion and 147 hectares of erosion, with an unchanged overall area of 2351 hectares, highlights a near balance between sediment deposition and erosion processes. This equilibrium indicates that while the river's overall area remains stable, localized sediment dynamics changes occur. Accretion fosters the formation of new habitats, potentially enhancing biodiversity, while erosion can lead to habitat loss and fragmentation, negatively impacting local species. Hydrologically, the balance suggests stable river flow patterns, though localized changes may affect flood risks and water quality. Socioeconomically, erosion threatens agricultural land and infrastructure, leading to potential economic losses, whereas accretion may offer new land for development, although it requires careful planning. From a geomorphological perspective, this dynamic balance influences river morphology, contributing to meandering channels and altering riverbank profiles. Effective river management must consider these processes, incorporating sediment management and conservation efforts to protect vulnerable ecosystems. Engaging local communities in managing these changes ensures sustainable practices that integrate local knowledge and needs. Overall, this balance underscores the importance of adaptive management strategies to maintain the river ecosystem's sustainability and resilience amidst changing environmental conditions. The Changes in areas of River Channels over the Study period are shown in Table 1. Figure 5 represents the erosion and accretion of Oyan River for the 2002-2011 and 2011-2023 periods.

Table 1: Change in Areas of River Channel over the Study Period

Years	Previous Years (Ha)	Next Years (Ha)	Unchanged Area (Ha)	Erosion (Ha)	Accretion (Ha)
2002-2011	2498	2507	2403	95	104
2011-2023	2507	2511	2294	213	213
2002-2023	2498	2511	2351	147	156

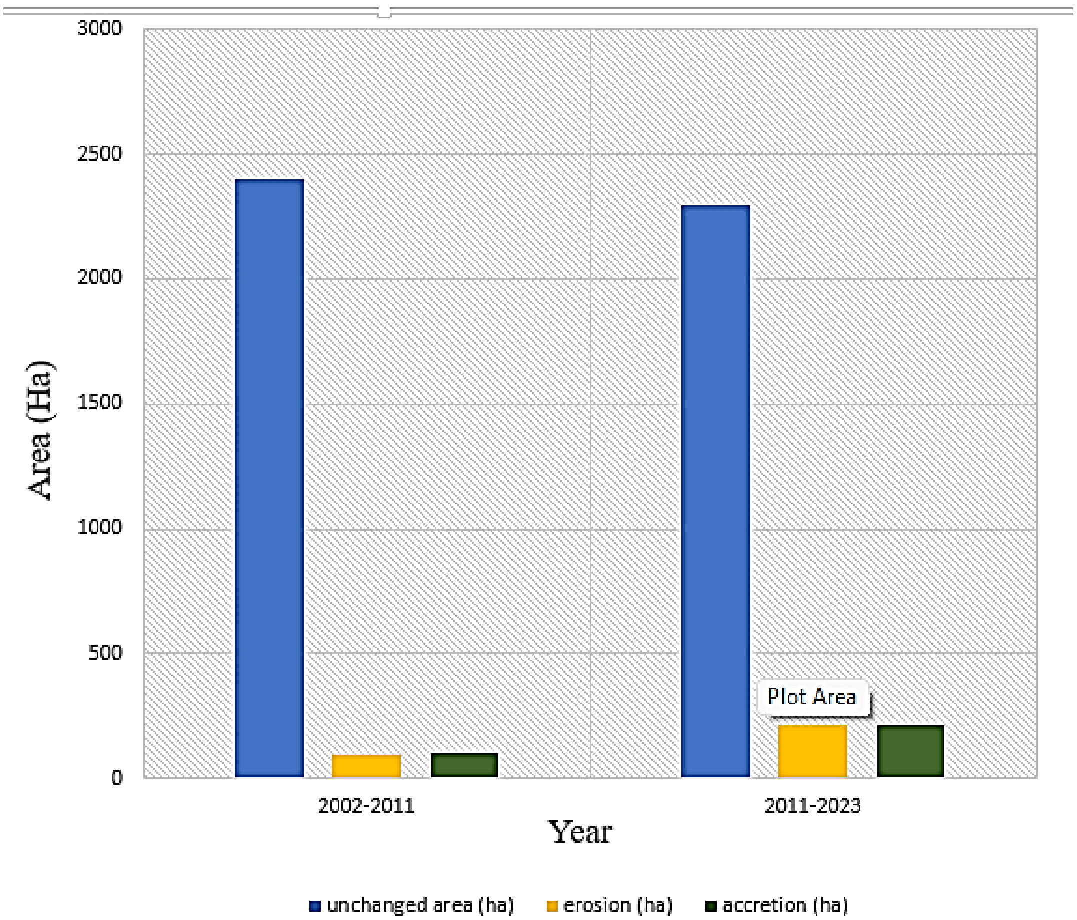

Figure 5: Histogram Depicting the Erosion & Accretion of Oyan River for 2002-2011 and 2023

5.0 CONCLUSION

This study successfully employed remote sensing technology to investigate riverbank erosion, accretion, and channel shifting in the Oyan River. Analysis of Landsat image data and Google Maps revealed significant bank erosion, leading to channel displacement from its original baseline course. Over the entire study period (2002–2023), 147 hectares underwent erosion, 156 hectares experienced accretion, and 2351 hectares remained stable. A critical period of accelerated erosion occurred between 2011 and 2023. Although spatial analysis showed noticeable but relatively minimal changes in the river channel over the study periods, the findings underscore the importance of effective land management and conservation practices to ensure the sustainable flow of the Oyan River.

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