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Geospatial Evaluation of Egbokodo River Basin in Warri South L.G.A, Delta State for Sustainable Agricultural Development

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Abstract: The geospatial evaluation of the Egbokodo River Basin in Warri South L.G.A, Delta State, is essential for sustainable agricultural development. This study employs Geographic Information System (GIS) and Remote Sensing techniques to analyze land cover, soil dynamics, and topographical features to assess agricultural suitability. The research utilizes multi-temporal datasets, including Landsat 9 imagery, Shuttle Radar Topography Mission (SRTM) data, and soil maps from the Nigerian Geological Survey Agency, to generate thematic maps and conduct suitability analyses.Results indicate that wetlands and water bodies constitute significant portions of the basin, highlighting the ecological richness and the need for conservation strategies. Agricultural suitability analysis classifies 42.25% of the study area as unsuitable for farming due to poor soil quality and hydrological constraints. However, 19.27% of the land is categorized as highly or very suitable, indicating potential for optimized agricultural practices with proper management. The findings underscore the necessity of sustainable land use planning, agroforestry, and soil conservation practices to enhance agricultural productivity while maintaining environmental integrity. The study concludes that integrating geospatial techniques into agricultural planning can aid in resource management and inform policy decisions. Recommendations include implementing wetland conservation programs, promoting climate-resilient farming methods, and optimizing land use strategies. This research provides a framework for balancing agricultural development with ecological sustainability in the Egbokodo River Basin.

Keywords: *Agricultural Suitability, Egbokodo, Geospatial Analysis, Remote Sensing and GIS, Sustainable Land use.*

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I. INTRODUCTION

Around ten to twelve thousand years ago, the human race began to domesticate plants and animals for food (Rosenberg, 2012). Before this first agricultural revolution, people mostly relied on hunting and gathering to obtain food supplies. Even though there are still groups of hunters and gatherers in the world today, most societies have switched to agriculture (Rosenberg, 2012). Rosenberg (2012) stipulated that the beginning of agriculture did not just occur in one place but appeared almost simultaneously around the world, possibly through trial and error with different plants and animals or by long term experimentation. Mabuza, P. S., Mahlalela, N., & Sodi, T. (2008). defined agriculture as the cultivation of land, raising and rearing of animals for the purpose of production of food for man, animals and industries. Agriculture involves and comprises crop production, livestock and forestry, fishery, processing and marketing of agricultural production. According to Rosenberg (2012), farming in the twentieth century became highly technological in more developed nations while less developed nations continued with practices which are similar to those developed after the first agricultural revolution, thousands of years ago. About 45% of the world's population rely on agriculture for their livelihood. The global population involved in agriculture ranges from about 2% in the United States to about 80% in some parts of Asia and Africa. There are two types of agriculture, subsistence and commercial. The majority of the world's population is involved in agricultural practice and subsistence agriculture to tend to their need for food (Aliber and Hart, 2009). Subsistence agriculture could potentially contribute to 2 household food security and livelihoods with well-developed support systems, hence the need for technological advancement in agriculture (Aliber and Hart, 2009).

A number of investigators have worked on basin morphometry in many parts of the world including Ndatuwong et al., 2014 In Nigeria, such works have been carried which includes those of (Eze and Efiong, 2010). In the regions of interest, the basins and the basin

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morphometry have been classified and analyzed. Drainage basin morphometric parameters are used to describe and compare basins of different sizes. Basin morphometry parameters include stream order, stream length, stream number, and basin area. Others are basin shape factor (eg. circularity ratio, elongation ratio, formation factor and compaction ratio), basin perimeter, bifurcation ratios, drainage density, stream frequency and drainage intensity. Close attention needs to be paid to sustainable management of water resources in order to harmonize management practices with natural conditions and limitations. In agricultural context, finding optimal locations for crops can increase economic benefits, as well as reduce negative environmental consequences. Basin characterization analysis is a prerequisite for sustainable agricultural production. It involves evaluation of the criteria ranging from basin morphometry to agro-economic multi-criteria decision-making techniques for suitability analysis.

As the world grapples with the imperative of sustainable development, the intersection of agriculture and river basin management takes center stage. The Egbokodo River Basin, a microcosm of broader environmental challenges, becomes a compelling subject for exploration. This study embarks on a journey to unravel the spatial intricacies of the basin, dissecting its land use patterns, soil dynamics, and topographical features to inform strategies for sustainable agricultural development.

The Egbokodo River Basin in Warri South, Delta State faces numerous challenges that hinder sustainable agricultural development. The current land use patterns and topographical features of the area may not be conducive for optimal agricultural productivity. Limited access to reliable geospatial data and inadequate land use planning strategies further exacerbate the challenges faced by farmers in the region. Therefore, there is a pressing need to conduct a geospatial evaluation of the Egbokodo River Basin to assess its potential for sustainable agricultural development based on evaluating soil dynamics, and examine topographical features that influence the basin's ecological resilience.

II. STUDY AREA DESCRIPTION

The Egbokodo River Basin is situated in Warri South Local Government Area of Delta State, Nigeria. The river basin covers a vast area of land, characterized by varying relief and drainage patterns.

- *Location*

The location of the basin is in the southern part of Nigeria, with coordinates ranging from 5.4692° N Latitude and, 5.8294° E Longitude. The basin is bounded by the Benin River to the west and the Forcados River to the east. The basin covers a significant land area within the state, extending from the western border with neighboring Edo State to the central region of Delta State. The Egbokodo River Basin is marked by a network of rivers, streams, and tributaries that flow through the region, including the Egbokodo River itself, which serves as a central watercourse in the basin. These waterways form part of the larger Niger Delta region, which is known for its intricate network of river channels and estuaries that drain into the Gulf of Guinea.

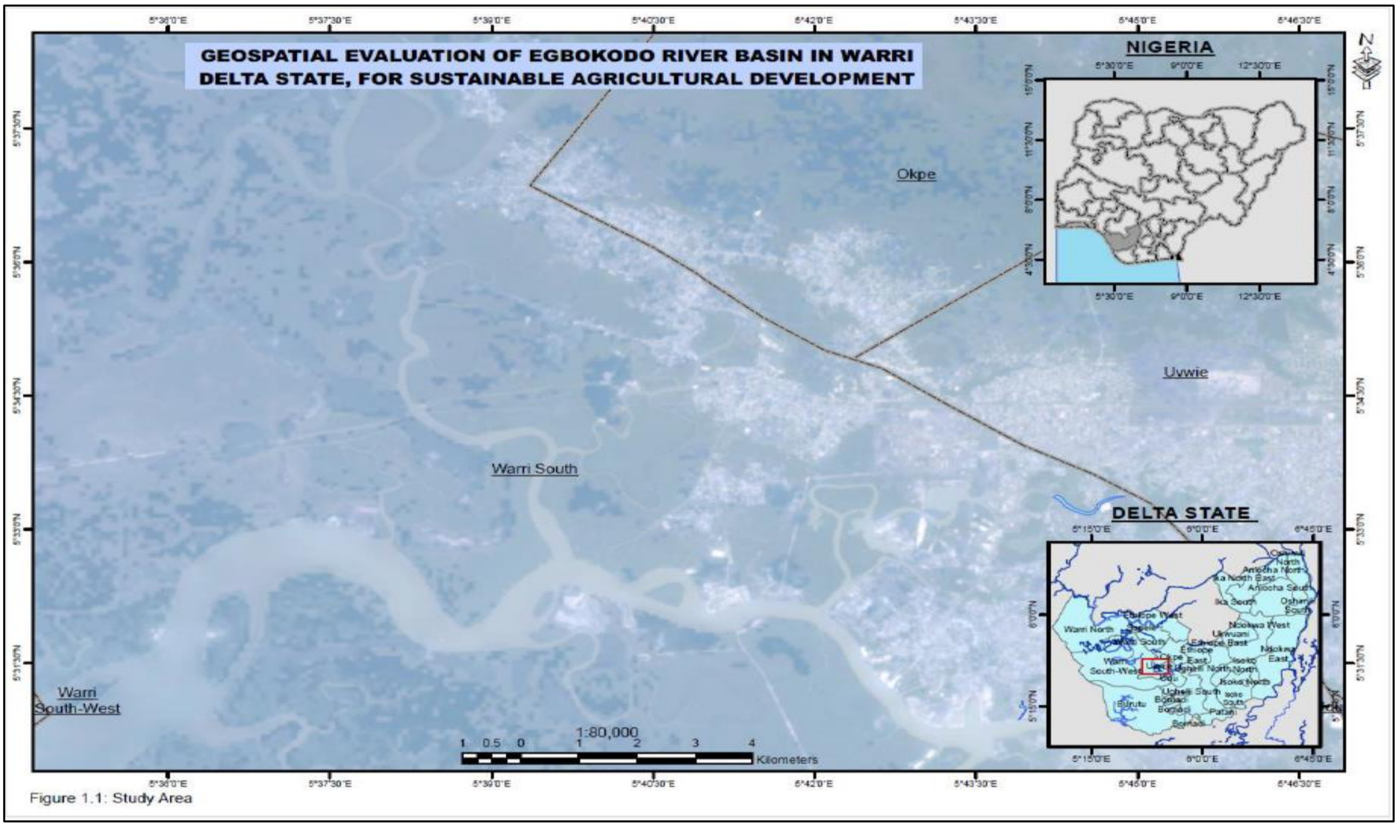

Fig 1 Map of Study Area.
Source: Researcher, 2004

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- *Relief and Drainage*

The relief of the Ebgokodo River Basin is relatively flat, with some low-lying areas and gentle slopes. The drainage pattern of the basin is dendritic, with numerous tributaries feeding into the main river channel. The main river channel of the Egbokodo River Basin flows in a southwesterly direction towards the Niger Delta region.

- *Soils*

The soil in the Egbokodo River Basin is predominantly sandy loam, characterized by a mixture of sand, silt, and clay particles. This soil type is highly fertile and well-drained, making it suitable for agricultural activities.

Sandy loam soil has good water retention capabilities while still allowing for adequate drainage, which is essential for the growth of crops. The soil structure also allows for good aeration, root penetration, and nutrient absorption by plants. Additionally, sandy loam soil is easy to work with and cultivate, making it ideal for farming practices.

The fertility of the soil in the Egbokodo River Basin is further enhanced by the presence of organic matter and nutrients. The rich soil supports the growth of a variety of crops, including root crops like cassava and yam, as well as cash crops like oil palm. The fertile soil also sustains the lush vegetation and diverse flora and fauna in the basin.

Farmers in the Egbokodo River Basin utilize different agricultural practices to optimize the productivity of the soil. These practices may include crop rotation, intercropping, and the use of organic fertilizers to maintain soil health and fertility. Proper soil management is crucial for sustaining agricultural production and ensuring long-term food security in the region.

The soil quality and fertility in the Egbokodo River Basin are valuable assets for sustainable agricultural development. By understanding the characteristics of the soil and implementi appropriate soil conservation practices, farmers can maximize crop yields, protect the environment, and promote agricultural sustainability in the basin.

- *Climate*

The climate in the Egbokodo River Basin is characterized by a typical tropical monsoon climate, with distinct wet and dry seasons. The region experiences high temperatures and high humidity levels throughout the year.

During the rainy season, which typically spans from April to October, the basin receives heavy rainfall. The average annual rainfall in the basin is around 2,000mm, with most of the precipitation occurring in the wet season. The rainfall is essential for agricultural activities, as it provides the necessary water for crop growth and sustains the river ecosystem.

The dry season in the Egbokodo River Basin, which typically lasts from November to March, is characterized by lower humidity levels and minimal rainfall. The dry season can be challenging for agriculture, as farmers may rely on irrigation or water storage to sustain their crops during this period.

- *Temperature*

The temperature in the Egbokodo River Basin remains high throughout the year, with average temperatures ranging from 25°C to 35°C. The region experiences little variation in temperature between day and night, with daytime temperatures often exceeding 30°C. The high temperatures, coupled with high humidity levels, can create a hot and humid environment in the basin.

- *Vegetation*

The vegetation in the Egbokodo River Basin is diverse and plays a crucial role in supporting the local ecosystem. The basin's tropical climate and fertile soil contribute to the growth of various plant species, creating a rich environment for flora and fauna.

The vegetation in the Egbokodo River Basin can be categorized into two main types: tropical rainforest and mangrove swamps. The tropical rainforest is characterized by dense, lush greenery and a wide variety of tree species, shrubs, and herbs. These forests provide habitat and food for a vast array of wildlife, including birds, mammals, and insects. Mangrove swamps are another important component of the basin's vegetation. These unique ecosystems are characterized by brackish water and salt-tolerant plants, such as mangrove trees. Mangrove swamps provide vital breeding grounds and nurseries for many fish and crustacean species, supporting the local fishing industry.

The vegetation in the Egbokodo River Basin also helps to regulate the local climate by providing shade, reducing soil erosion, and maintaining biodiversity. Trees and plants in the basin play a crucial role in absorbing carbon dioxide, releasing oxygen, and mitigating the effects of climate change. Additionally, the vegetation in the Egbokodo River Basin has economic importance for the local communities. The forests provide resources for timber, fuelwood, and non-timber forest products. Traditional medicine, food, and craft materials are also sourced from the diverse plant species in the basin. Conservation of the vegetation in the Egbokodo River Basin is essential for maintaining the ecological balance and ensuring the sustainability of the local environment.

Protection of the forests, mangrove swamps, and other natural habitats in the basin can help preserve biodiversity, support wildlife populations, and promote ecotourism opportunities.

- *Socio-Economic Activities*

Socio-economic activities in the Egbokodo River Basin primarily revolve around agriculture, fishing, and small-scale trading. The fertile soil in the basin supports the cultivation of crops such as cassava, yam, and oil palm. Fishing is also a significant economic activity, as the river basin is home to a variety of fish species. Additionally, small-scale trading thrives in the basin, with local markets serving as hubs for economic activity.

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III. METHODOLOGY

➢ *Preamble*

In the quest to unravel the intricate dynamics of sustainable agricultural development within the Egbokodo River Basin, our methodology hinges on the adept utilization of cutting-edge technologies. Geographic Information System (GIS) and Remote Sensing emerge as the dynamic duo, poised to illuminate the landscape with unparalleled precision. This section delves into the significance of these methodologies, elucidating their roles in capturing, analyzing, and synthesizing crucial spatial data that will form the bedrock of our research.

➢ *Data Collection and Characteristics*

The geospatial evaluation of the Egbokodo River Basin in Warri South Local Government Area of Delta State for sustainable agricultural development relies on a comprehensive analysis of diverse datasets, each contributing unique insights into the basin's physical and environmental characteristics. The 2024 Landsat 9 imagery, with its spatial resolution of 30 and 15 meters and spectral resolution encompassing visible (Red, Green, Blue), near-infrared (NIR), and shortwave infrared (SWIR 1 and SWIR 2) bands, provides critical information for land use and land cover classification, as well as the calculation of the Normalized Difference Vegetation Index (NDVI). These deliverables are essential for understanding vegetation health, land cover changes, and agricultural potential over time. Complementing this, the 2016 Shuttle Radar Topography Mission (SRTM) data, with a 30-meter spatial resolution, offers detailed topographic information, including slope, elevation, flow direction, and agricultural suitability modeling. This dataset is invaluable for identifying areas prone to erosion, waterlogging, or other topographical constraints that could impact agricultural productivity. Furthermore, the 2012 soil map from the Nigerian Geological Survey Agency, at a scale of 1:100,000, provides a detailed characterization of soil types and geological features within the basin. This information is crucial for assessing soil fertility, drainage, and suitability for various crops, thereby guiding sustainable agricultural practices. Together, these datasets, sourced from reputable platforms like the USGS Earth Explorer and the Nigerian Geological Survey Agency, form a robust foundation for the geospatial evaluation of the Egbokodo River Basin, enabling informed decision-making for sustainable agricultural development in the region.

Table 1 Data Characteristics

Date	Data type	Spatial resolution	Spectral resolution	Deliverables	Source
2024	Landsat 9	30 and 15m	R, G, B, NIR, SWIR 1 and SWIR 2	Land use land cover classification and NDVI	USGS Earthexplorer.usgs.gov
2016	SRTM	30m	-	Slope, Elevation, Flow direction, Topographic modelling of agricultural suitability	USGS Earthexplorer.usgs.gov
2012	Soil map	1:100,000	-	Soil and geological characterization	Nigerian Geological Survey Agency

➢ *Image Analytic Framework*

The presented methodological framework (see Figure 2) offers a systematic approach to identifying suitable sites for sustainable agriculture within a river basin, leveraging remote sensing and GIS technologies. The process initiates with the identification of suitable sensors, which is paramount to acquiring accurate and relevant data. This initial step ensures that the subsequent processes are grounded in reliable information.

The framework bifurcates into two distinct paths: Landsat/Sentinel and SRTMASTER. The Landsat/Sentinel path focuses on satellite imagery, beginning with the identification of bands of interest. This step is followed by a series of meticulous processes including preprocessing, subsetting, geometric correction, classification, and reclassification. Each of these stages is crucial in refining the satellite data to accurately represent the geographic and environmental variables of the study area.

Conversely, the SRTM/ASTER path involves the integration of various data types, such as Digital Elevation Model (DEM), slope, stream order, and watershed & catchment area. These data types undergo reclassification, which is essential for standardizing the information for comparative analysis. The reclassified data are subsequently integrated, reclassified once more, and further integrated to yield a comprehensive analysis of the potential agricultural sites.

The culmination of this methodological framework is the creation of a final map, which delineates the suitable sites for sustainable agriculture. This final map is not merely a visual representation but a strategic tool that informs decision-making processes, ensuring that the selected sites are optimal for sustainable agricultural practices.

In essence, this framework embodies a holistic and iterative approach, integrating diverse data sources and processing techniques to achieve a robust analysis. By doing so, it facilitates the identification of optimal locations for agriculture, thereby promoting sustainable land use practices and contributing to environmental conservation.

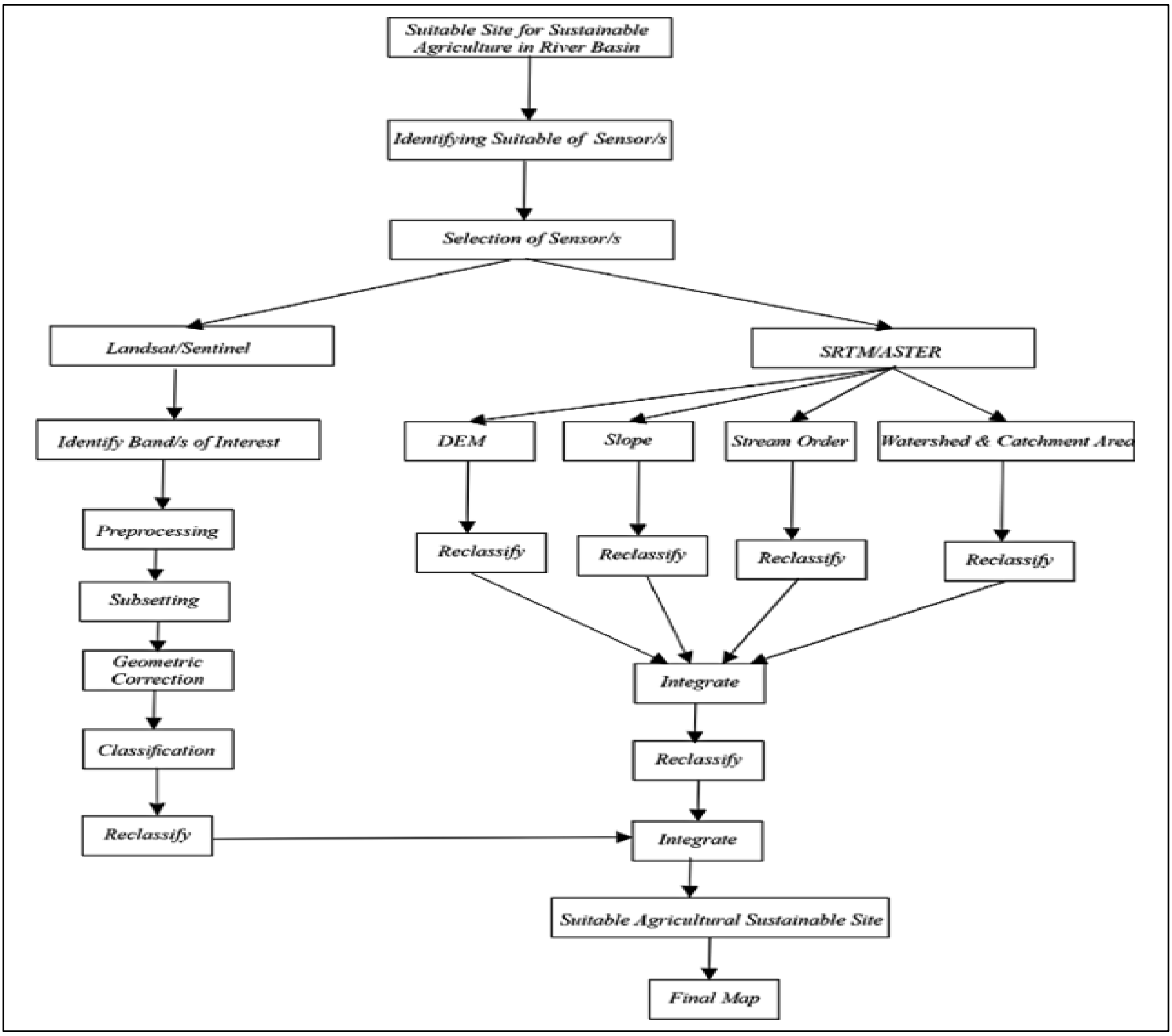

Fig 2 Research Methodological Framework.
Source: Researcher, 2024.

IV. RESULTS AND ANALYSIS

➢ *Land Cover Characteristics Map*

The land cover map statistics for the study area reveal a diverse landscape, with different land use/land cover classes occupying varying extents and proportions. Each class plays a significant role in the ecological and socio-economic dynamics of the region.

The largest land cover class in the study area is wetlands, covering an extensive area of 97,329.43 hectares (973.29 square kilometers), which constitutes 42.25% of the total area. Wetlands are crucial ecosystems, providing a range of services such as water filtration, flood control, and habitat for various species. The prominence of wetlands in this area highlights the region's ecological richness and the need for their preservation and sustainable management.

Following wetlands, water bodies cover 53,827.18 hectares (538.27 square kilometers), accounting for 23.36% of the total area. Water bodies are vital for maintaining the hydrological cycle, supporting aquatic life, and providing water for human use and agriculture. The significant presence of water bodies underscores the importance of water resource management in the region.

Vegetation, which includes forests, grasslands, and other natural covers, occupies 44,236.54 hectares (442.37 square kilometers), making up 19.20% of the total area. Vegetation plays a crucial role in carbon sequestration, soil conservation, and biodiversity support. The distribution of vegetation in the study area indicates the potential for conservation efforts and sustainable land use practices.

Built-up areas, encompassing urban and infrastructural developments, cover 34,989.21 hectares (349.89 square

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kilometers), representing 15.19% of the total area. The extent of built-up areas reflects the level of urbanization and development within the region. Effective urban planning and sustainable development strategies are essential to balance growth with environmental conservation.

In summary, the land cover statistics provide valuable insights into the composition and distribution of different land use/land cover classes within the study area. Each class's extent and percentage highlight their importance and the need for tailored management and conservation efforts. By understanding these dynamics, policymakers and stakeholders can make informed decisions to promote sustainable development and environmental stewardship in the region.

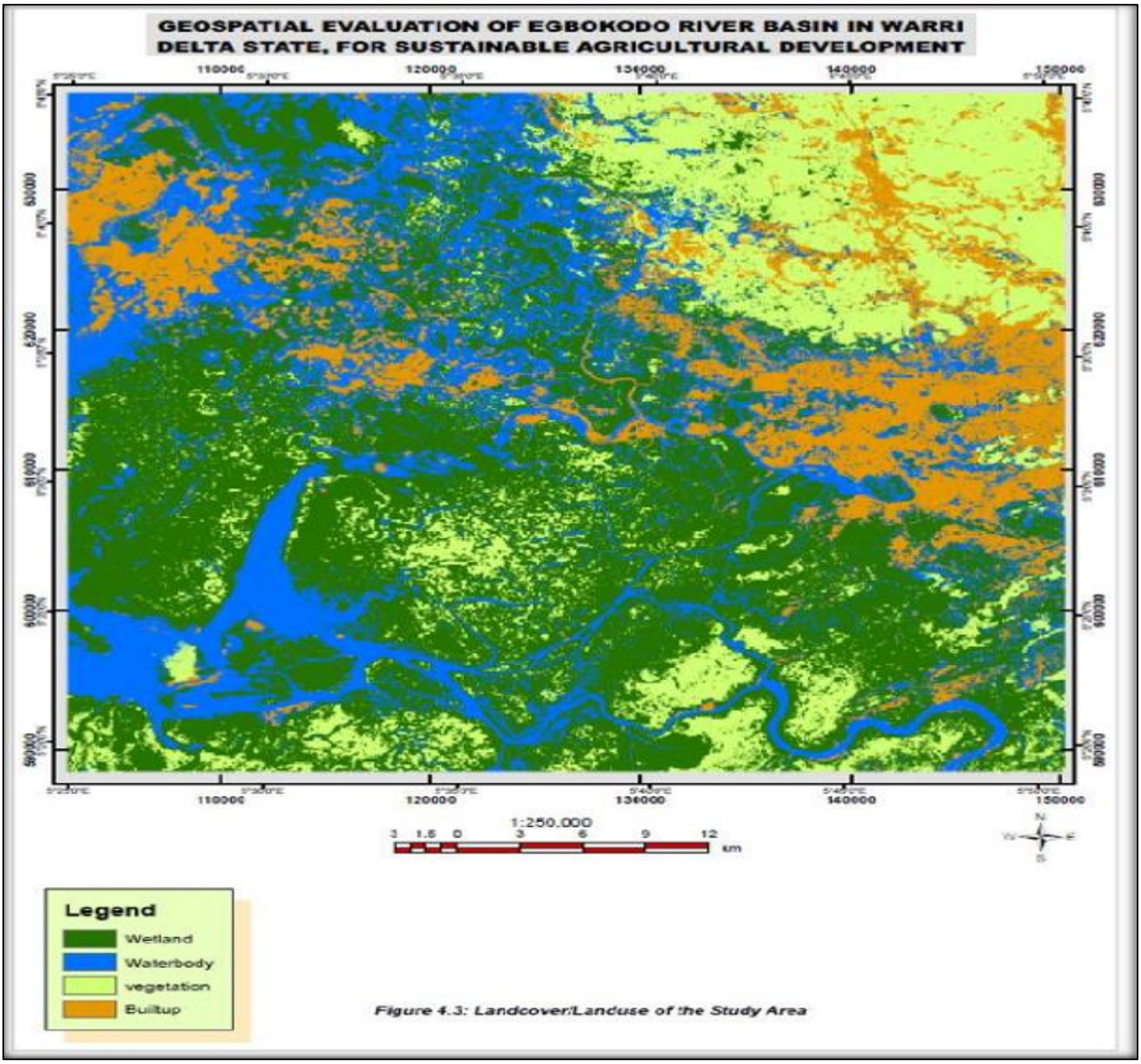

Fig 3 Landcover of the Study Area

➢ *Suitability Analysis*

The agricultural suitability classification within the study area provides a comprehensive understanding of how different parts of the region are assessed for agricultural purposes. These classes are essential for effective land use planning, ensuring that agricultural activities are carried out in areas where they are most likely to thrive and contribute to sustainable development.

The largest portion of the study area, comprising 97,329.86 hectares (973.30 square kilometers), is classified as unsuitable for agriculture, making up 42.25% of the total area. This classification highlights the presence of certain limiting factors such as poor soil quality, steep slopes, or unfavorable climate conditions that make agriculture impractical or unsustainable in these regions. By identifying

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these unsuitable areas, efforts can be directed towards their conservation or alternative land use.

Moderately suitable areas cover 64,027.16 hectares (640.27 square kilometers), accounting for 27.79% of the study area. These lands have some limitations that may affect crop productivity, such as soil fertility issues, water availability, or moderate slope gradients. With appropriate management practices and interventions, these moderately suitable areas can still support successful agricultural activities, albeit with lower yields compared to highly suitable lands.

Suitable areas, which span 24,630.94 hectares (246.31 square kilometers) and constitute 10.69% of the total area, possess favorable conditions for agriculture. These regions have good soil quality, adequate water supply, and manageable slopes. Farmers can achieve satisfactory yields with standard agricultural practices in these suitable areas, making them valuable assets for food production.

Very suitable areas, covering 25,966.50 hectares (259.67 square kilometers) and representing 11.27% of the study area, exhibit optimal conditions for agriculture. These lands are characterized by high soil fertility, ample water availability, and gentle slopes. The very suitable classification indicates that these areas can support a wide range of crops with minimal input and management efforts, making them ideal for agricultural expansion.

Lastly, highly suitable areas encompass 18,427.89 hectares (184.28 square kilometers), making up 8.00% of the total area. These lands offer the best conditions for agriculture, with exceptional soil quality, consistent water supply, and flat or gently sloping terrain. Highly suitable areas are prime locations for intensive agricultural activities, ensuring maximum productivity and sustainable land use.

Thus, the agricultural suitability classification within the study area provides a detailed assessment of the land's potential for agricultural use. By understanding the distribution of unsuitable, moderately suitable, suitable, very suitable, and highly suitable areas, policymakers and stakeholders can make informed decisions to optimize land use, enhance agricultural productivity, and promote sustainable development in the region.

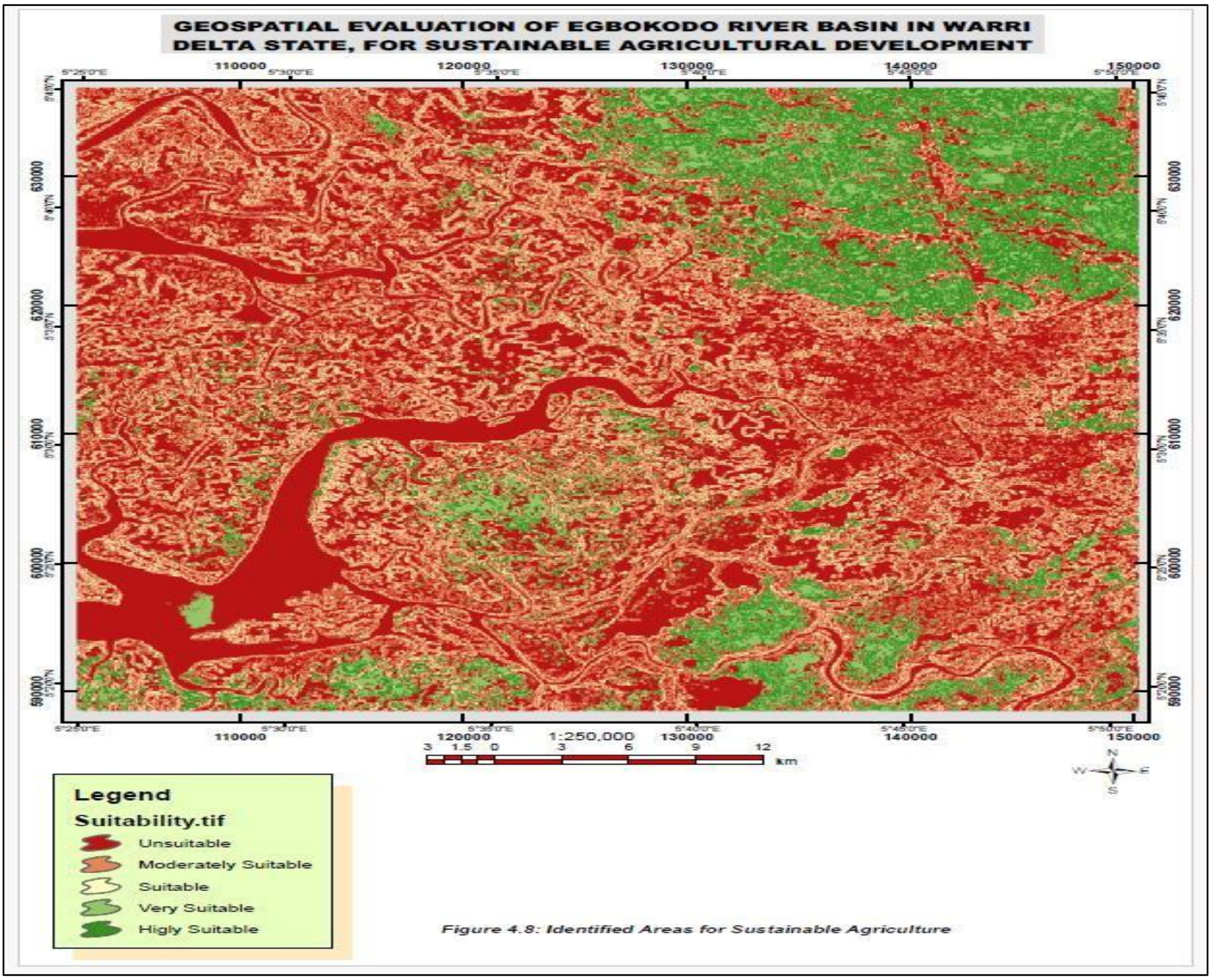

Fig 4 Suitability Areas for Sustainable Agriculture

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V. DISCUSSION

The geospatial evaluation of the Egbokodo River Basin in Warri South L.G.A, Delta State, for sustainable agricultural development provides significant insights into the region's potential for fostering sustainable farming practices. The study utilizes advanced geospatial techniques, including remote sensing and GIS, to analyze the land cover, land use, and agricultural suitability of the area.

Firstly, the land cover analysis reveals a diverse landscape with significant portions of wetlands, water bodies, vegetation, and built-up areas. The predominance of wetlands, covering 42.25% of the study area, indicates the region's ecological richness. Wetlands are known for their vital ecological functions, such as water purification, flood control, and habitat provision. However, their extensive presence also suggests potential limitations for conventional agriculture, necessitating careful consideration of suitable agricultural practices that do not compromise the wetlands' ecological integrity.

The significant presence of water bodies, making up 23.36% of the area, underscores the importance of water resource management in the region. The availability of water is a critical factor for agricultural activities, and the proper management of these water bodies can support sustainable irrigation practices, ensuring a reliable water supply for crops.

Vegetation, accounting for 19.20% of the study area, plays a crucial role in maintaining ecological balance and supporting biodiversity. The presence of natural vegetation areas highlights the potential for agroforestry practices, which integrate trees and shrubs into agricultural systems, providing multiple benefits such as soil conservation, carbon sequestration, and enhanced biodiversity.

The built-up areas, comprising 15.19% of the study area, reflect the level of urbanization and infrastructural development within the region. Urban expansion can pose challenges to agricultural development by reducing the availability of arable land. Therefore, it is essential to adopt sustainable urban planning strategies that balance growth with the preservation of agricultural lands.

The agricultural suitability analysis further refines our understanding of the region's potential for farming. The classification reveals that a substantial portion of the area, 42.25%, is unsuitable for agriculture, likely due to factors such as poor soil quality, steep slopes, or unfavorable climatic conditions. Identifying these unsuitable areas helps in directing agricultural activities to more viable regions, thereby optimizing land use.

Moderately suitable areas, covering 27.79% of the study area, indicate regions with some limitations that can affect crop productivity. However, with appropriate management practices, these areas can still support successful agricultural activities. Suitable, very suitable, and highly suitable areas, constituting 10.69%, 11.27%, and 8.00% of the study area respectively, offer favorable conditions for agriculture. These regions possess good soil quality, adequate water supply, and manageable slopes, making them prime locations for agricultural expansion.

In summary, the geospatial evaluation of the Egbokodo River Basin provides a comprehensive understanding of the region's land cover, land use, and agricultural suitability. The findings highlight the need for a balanced approach that considers ecological conservation, water resource management, and sustainable agricultural practices. By leveraging advanced geospatial techniques, policymakers and stakeholders can make informed decisions to promote sustainable agricultural development in the Egbokodo River Basin, ensuring food security, economic growth, and environmental stewardship.

VI. CONCLUSION

In conclusion, the geospatial evaluation of the Egbokodo River Basin in Warri South L.G.A, Delta State, for sustainable agricultural development, offers valuable insights into the region's land cover, land use, and agricultural suitability. The study reveals a diverse landscape with significant portions of wetlands, water bodies, vegetation, and built-up areas, each playing a crucial role in the region's ecological and socio-economic dynamics.

The land cover analysis highlights the importance of wetlands and water bodies, underscoring the need for their preservation and sustainable management. The presence of natural vegetation areas emphasizes the potential for agroforestry practices, while the extent of built-up areas reflects the level of urbanization and the need for balanced urban planning.

The agricultural suitability classification further refines our understanding of the region's potential for farming. By identifying unsuitable, moderately suitable, suitable, very suitable, and highly suitable areas, the study provides a comprehensive assessment of the land's potential for agricultural use. This information is essential for optimizing land use, enhancing agricultural productivity, and promoting sustainable development in the region.

Overall, this geospatial evaluation serves as a robust foundation for informed decision-making, guiding policymakers and stakeholders in fostering sustainable agricultural practices, ensuring food security, and promoting environmental stewardship in the Egbokodo River Basin. By leveraging advanced geospatial techniques, the study contributes to the sustainable development of the region, balancing ecological conservation with socio-economic growth.

The recommendation of the study is as follows based on the findings from the geospatial evaluation of the Egbokodo River Basin:

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- Implement Sustainable Wetland Management Practices: Given that wetlands constitute 42.25% of the study area, it is crucial to develop and implement sustainable management practices that preserve their ecological functions. Efforts should focus on protecting wetland habitats, preventing pollution, and promoting the sustainable use of wetland resources to support both biodiversity and local communities.
- Promote Agroforestry and Sustainable Agricultural Practices: For areas classified as suitable, very suitable, and highly suitable for agriculture, encourage the adoption of agroforestry and sustainable farming techniques. These practices can enhance soil fertility, improve water management, and increase crop productivity while maintaining ecological balance. Support for training, resources, and incentives for local farmers can facilitate the transition to sustainable agriculture.
- Optimize Land Use Planning and Urban Development: To balance urban expansion with agricultural development, implement comprehensive land use planning strategies. Designate specific zones for urban development, agricultural activities, and conservation areas to ensure that each land use type is optimized. Sustainable urban planning should aim to minimize the encroachment on arable land and promote green infrastructure to support ecological sustainability.

These recommendations aim to foster a harmonious balance between ecological conservation, agricultural productivity, and urban development, ensuring the sustainable development of the Egbokodo River Basin.

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APPENDIX

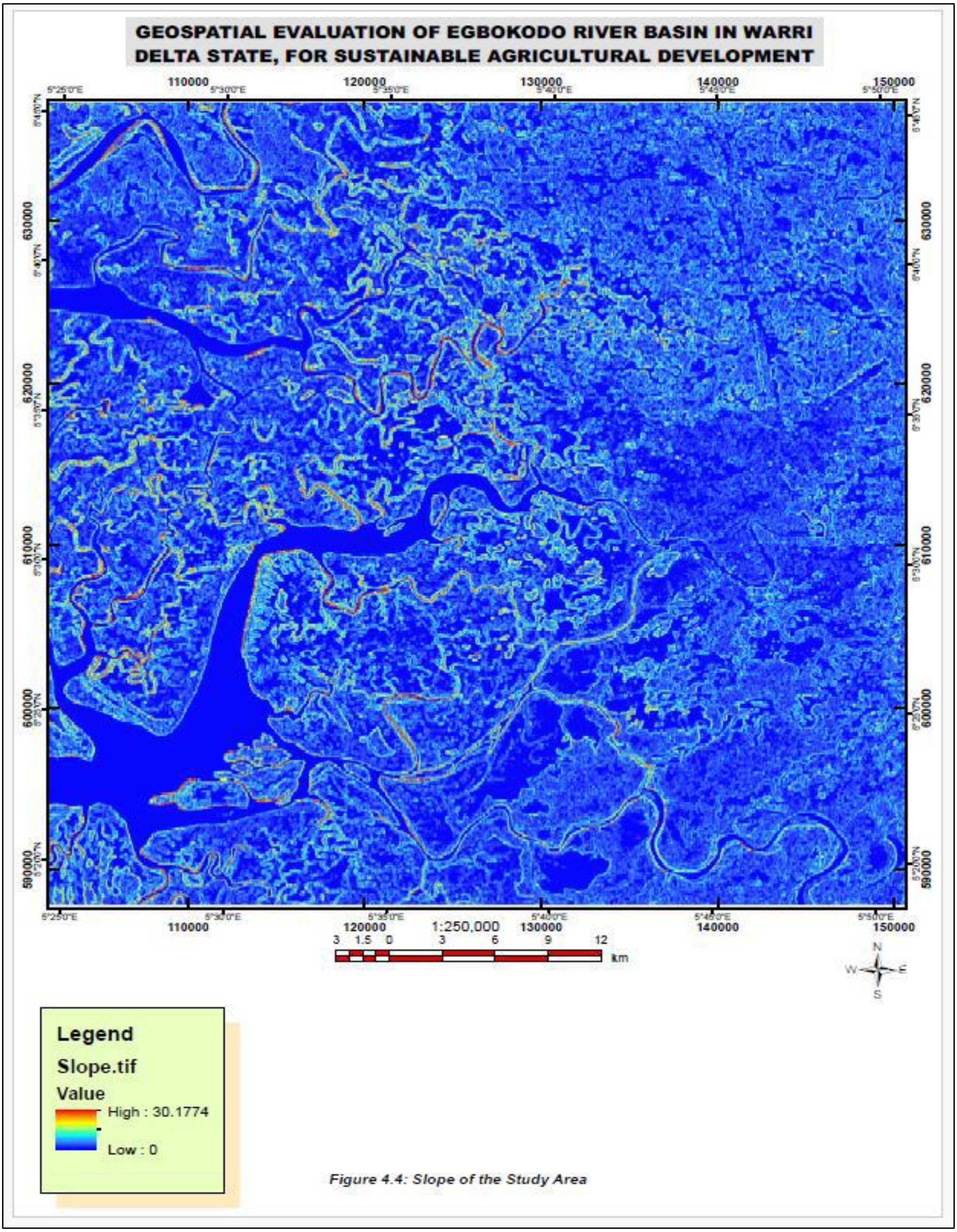

Fig 5 Slope Map of the Study Area

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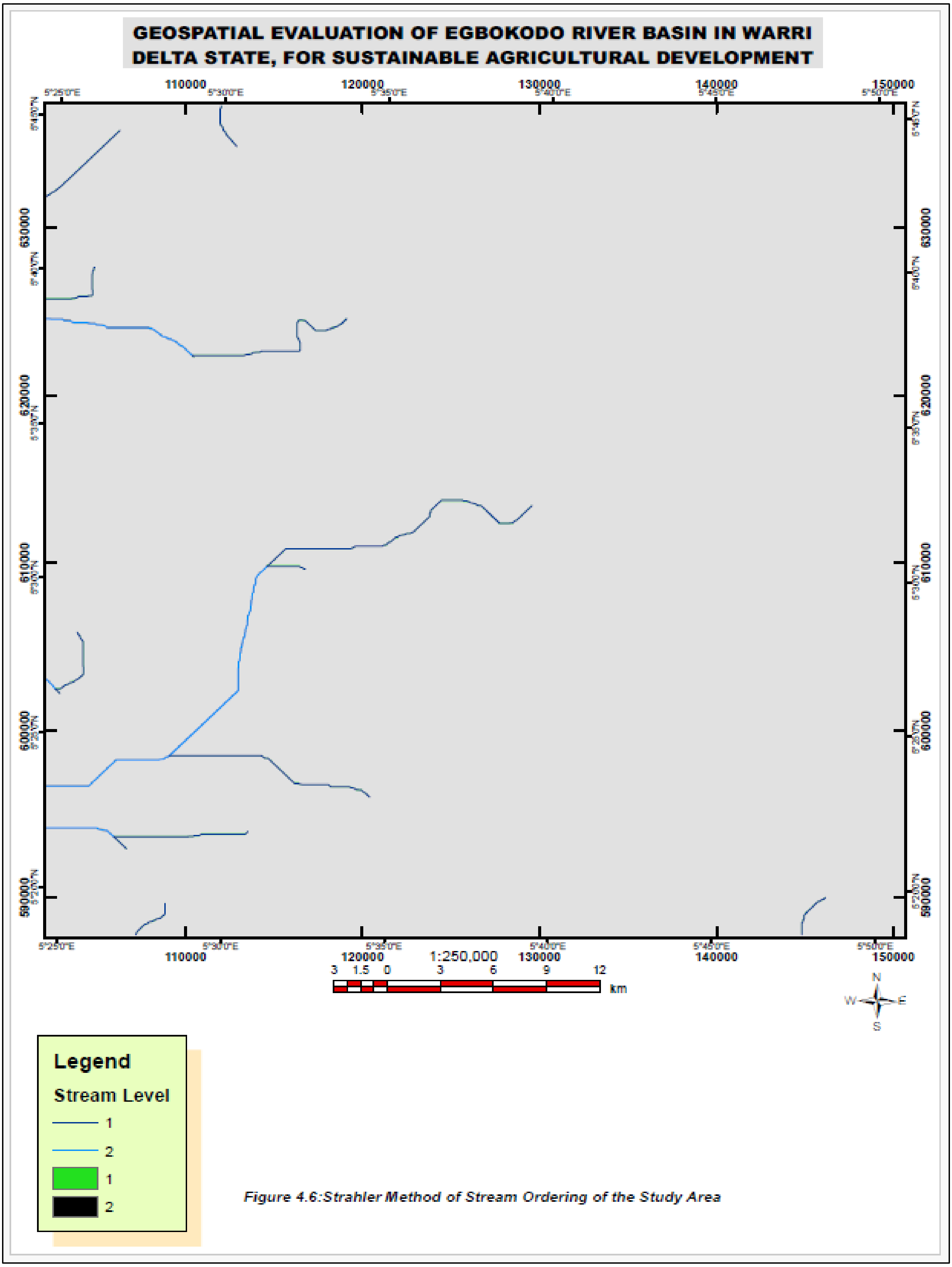

Fig 6 Stream Order of the Study Area

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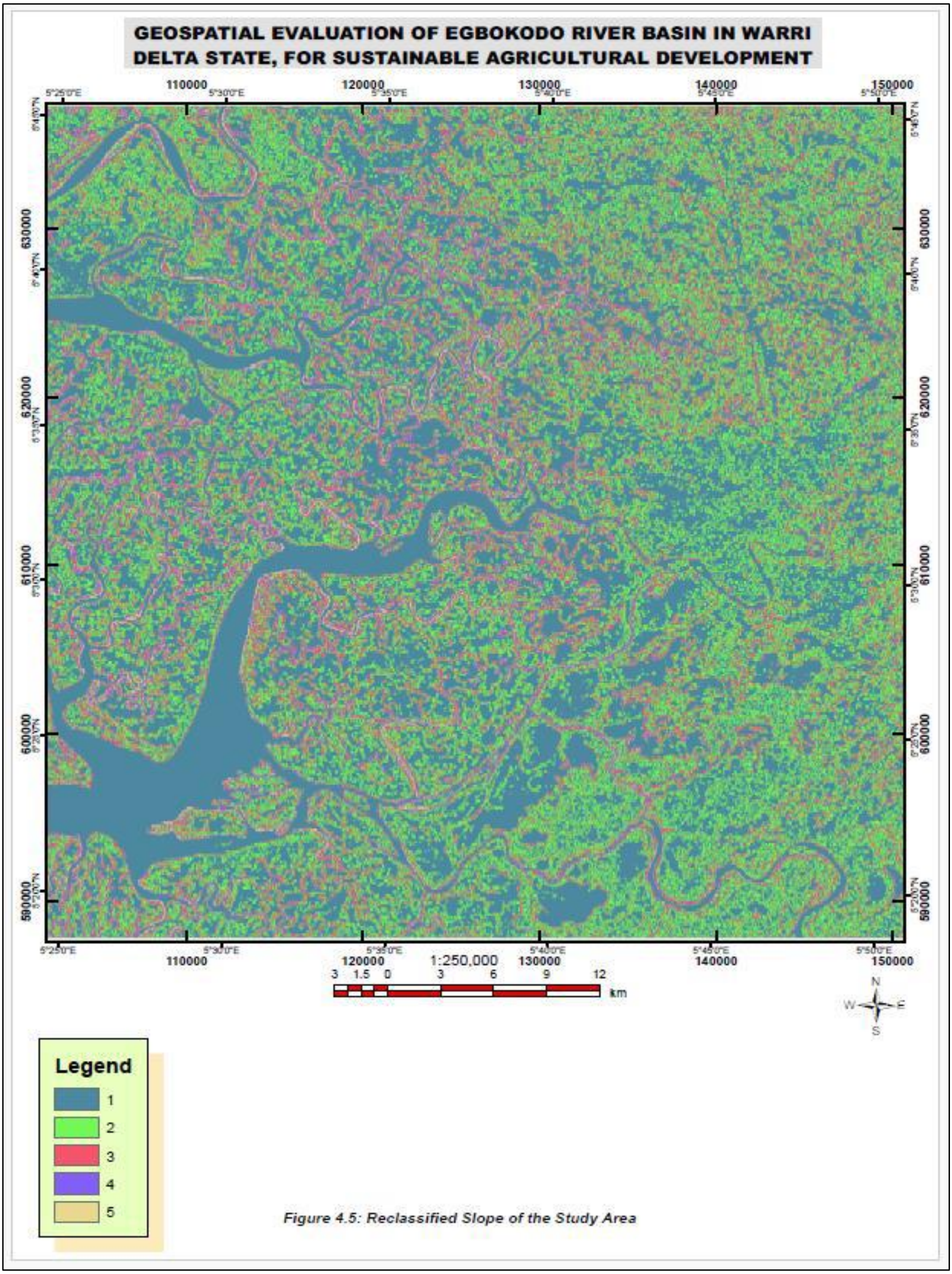

Fig 7 Reclassify Order of Study Area

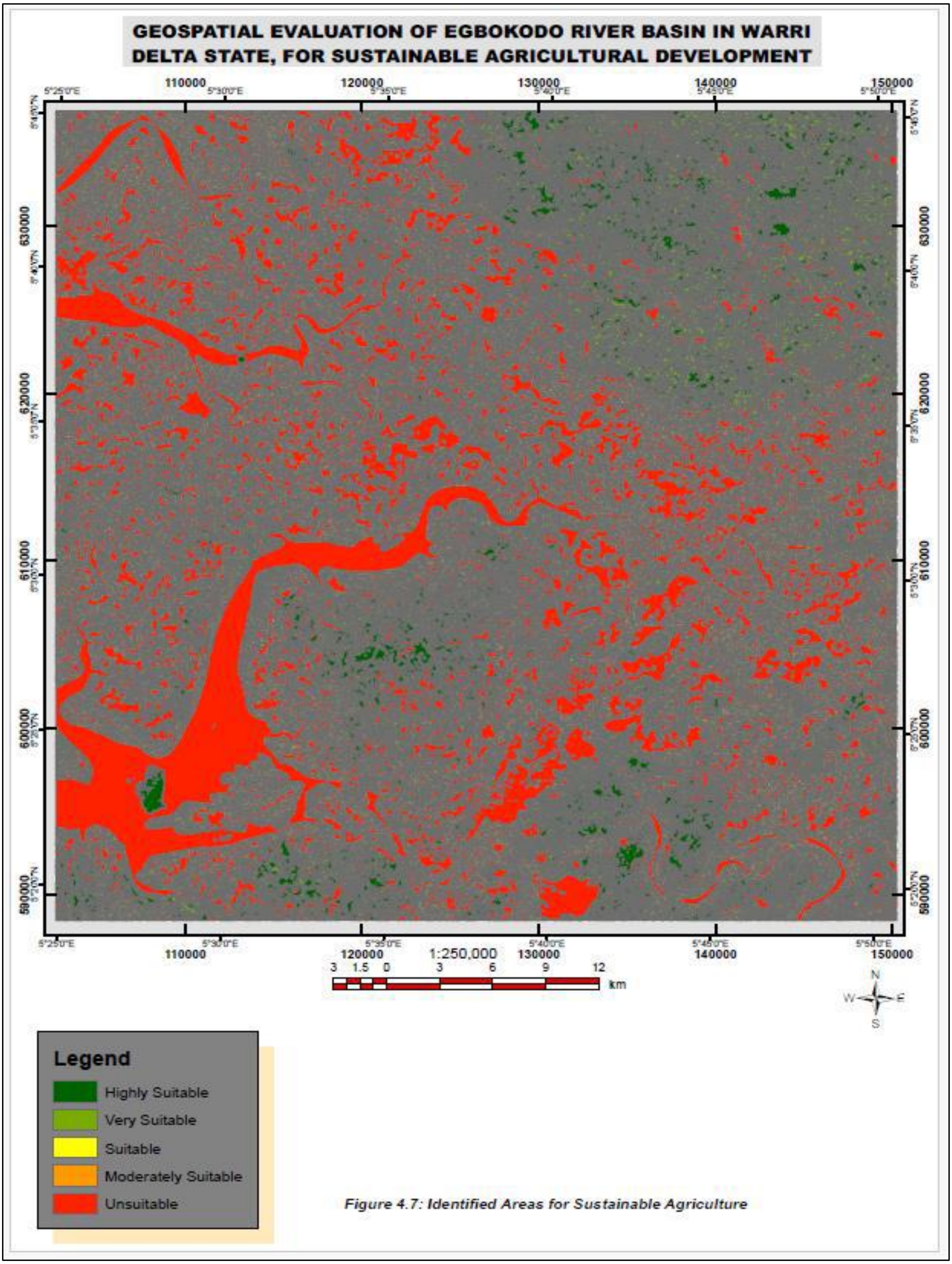

Fig 8 Sustainable Agricultural Suitability Map