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Digital Mapping to Determine Sustainability of Dam Construction in Owerri North for Agricultural Productivity

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Abstract

Agriculture is critical for economic stability and food security, particularly in regions like Owerri North, Nigeria, where inconsistent rainfall, waterlogging, and soil erosion threaten productivity. This study leverages Geographic Information Systems (GIS) and Remote Sensing (RS) to identify suitable dam construction sites to improve agricultural productivity. Key thematic layers such as precipitation, stream density, geomorphology, geology, land use/land cover (LULC), and elevation were analyzed. Data were sourced from global satellite missions like TRMM, Earth Explorer, and CHIRPS, high-resolution DEMs (e.g., SRTM), and local geological surveys. Using the Dam Suitability Stream Model (DSSM), this study employed GIS-based Multi-Criteria Decision Making (MCDM) techniques, including the Analytic Hierarchy Process (AHP), to assign weights to criteria such as stream order, slope, and land use. The analysis generated two suitability maps: Suitability on Stream and Overall Suitability. The Suitability on Stream map highlighted highly suitable zones near high-order streams in the basin's upper reaches, prioritizing areas with consistent water flow and favorable slopes (5% - 15%). In contrast, the Overall Suitability map expanded the scope to include broader factors like Euclidean distance from streams, identifying additional areas in the lower reaches, though many faced limitations such as lower stream orders and flood risks. Detailed evaluations of two proposed sites revealed that Dam Site 1, located on a third-order stream with a 88 km^2 catchment area, was the most viable option for multipurpose use, including irrigation and flood control. Dam Site 2, with a smaller catchment area and second-order stream, showed moderate suitability for smaller-scale projects. 3D surface models and cross-sectional analyses confirmed that Dam Site 1 had higher volumetric potential and better geological stability, making it more sustainable for agricultural water management. Therefore, integrating digital mapping and AHP is an efficient method for sustainable dam site selection, directly addressing water resource challenges and enhancing agricultural resilience.

Subject Areas

Agricultural Engineering

Keywords

GIS, Remote Sensing, Mapping, Dam

1. Introduction

Agriculture is a cornerstone of economic growth and societal well-being, playing a critical role in food security, employment, and national income [1]. In developed nations, agriculture supports industrial and trade advancements, contributing significantly to national economies [2]. In contrast, developing countries like Nigeria rely heavily on agriculture for rural livelihoods and employment, with the sector employing nearly 68% of the workforce and contributing approximately 30% to the national GDP [3]. However, rapid population growth, urbanization, and resource constraints exacerbate challenges such as erratic rainfall, soil degradation, and water scarcity, threatening agricultural sustainability [4]. These issues emphasize the urgent need for innovative solutions, such as dam construction, to ensure reliable water resources, support irrigation, and mitigate climate change impacts [5].

Dams play a transformative role in agricultural productivity by stabilizing water supplies, enabling consistent crop yields during dry seasons, and reducing sedimentation through runoff control [6]. Properly constructed dams also regulate water flow, reducing flood risks and enhancing resilience to climate variability [7]. The integration of Geographic Information Systems (GIS) and Remote Sensing (RS) technologies offers a powerful approach to optimizing dam placement by analyzing spatial data on hydrology, geology, topography, and land use [8]. These tools ensure dams maximize water availability while minimizing environmental and social impacts, as demonstrated in watershed management frameworks [9].

In Nigeria, where smallholder farmers dominate the sector and rely on outdated practices and rain-fed agriculture, government interventions like River Basin Development Authorities and Agricultural Development Projects (ADPs) have had limited success due to insufficient adoption of modern technologies [10]. For instance, the Lower Benue River Basin remains highly vulnerable to climate variability, underscoring the need for strategic dam construction to improve irrigation capacity and soil health [11]. Studies emphasize that GIS and RS applications could bridge these gaps by enabling data-driven decision-making [12].

This study leverages GIS and RS technologies to address agricultural challenges in Owerri North by digitally mapping land suitability for dam construction. Using methods such as Digital Elevation Model (DEM) analysis, slope classification, and the Analytic Hierarchy Process (AHP), the research integrates topographical, hydrological, and environmental data to identify optimal dam sites [13] [14]. The framework aims to improve water resource management, enhance agricultural productivity, and promote sustainable development, offering a scalable solution for regions facing similar challenges [7].

2. The Study Area

Owerri North, located between Latitudes 5˚24'N and 5˚36'N and Longitudes 6˚58'E and 7˚10'E in Imo State, Nigeria, spans about 198 square kilometers. The area is characterized by flat to gently undulating terrain with elevations ranging between 100 and 150 meters above sea level. Its tropical climate, with an average annual rainfall of 2250 mm, supports agriculture, but also contributes to waterlogging and erosion, making water management a key concern. **Figure 1** shows the map of the study area.

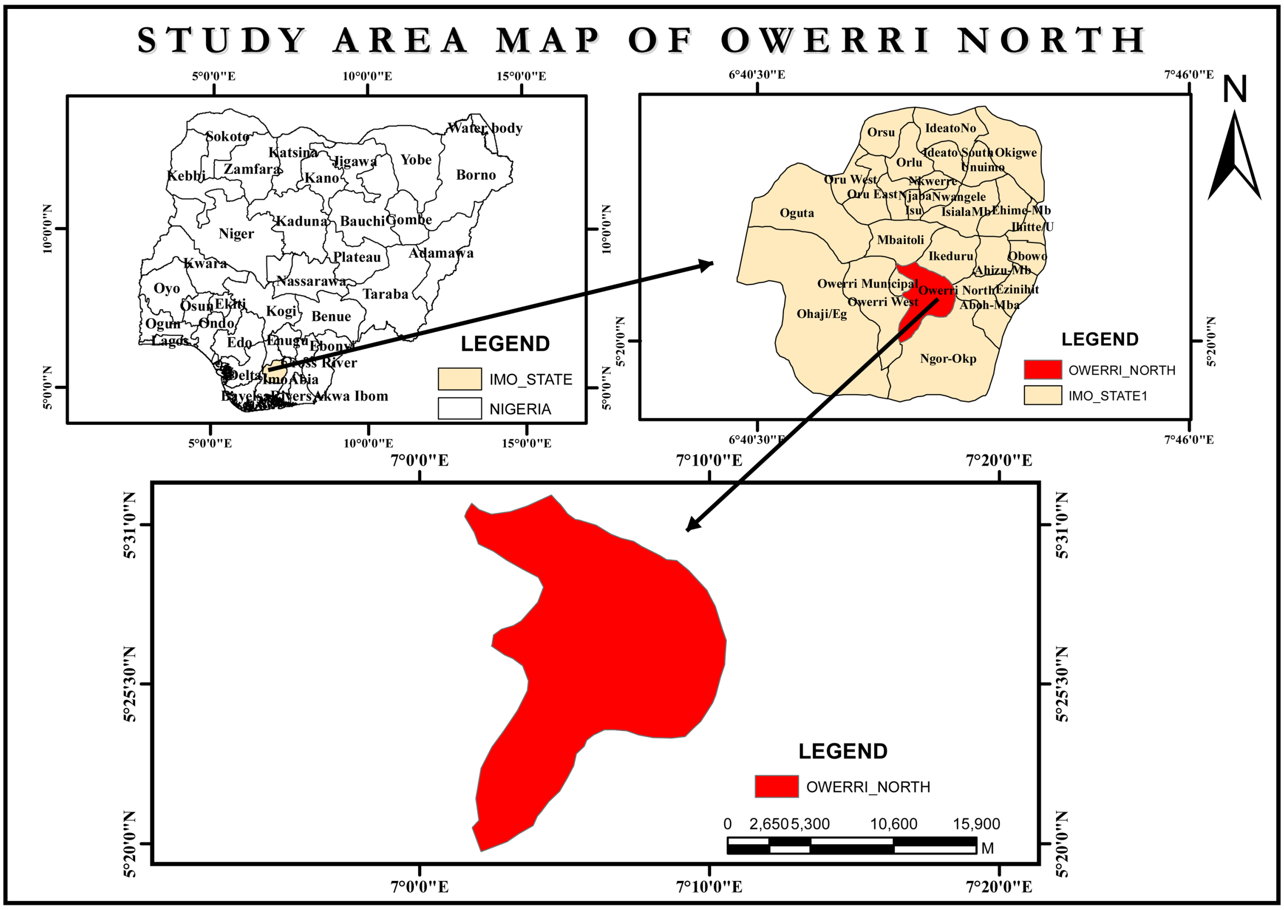

Figure 1. Study area map of Owerri North.

3. Methodology

As illustrated in Figure 2, the methodology for assessing dam suitability for agricultural productivity integrates thematic maps derived from diverse datasets, incorporating criteria such as precipitation, drainage density, geomorphology, geology, curve number (CN), elevation, and land use/land cover (LULC) to evaluate physical, hydrological, and environmental characteristics [15] [7]. Precipitation data, sourced from satellite products like TRMM and CHIRP, are spatially interpolated to model water availability patterns, while drainage networks and density are calculated using DEMs such as SRTM to assess hydrological connectivity [6] [7]. Geomorphological and geological features, refined through satellite imagery (e.g., Landsat 8) and field surveys, are critical for identifying stable dam foundations and erosion-prone areas 59. The CN method, which integrates soil type and LULC to estimate runoff potential, can be applied to evaluate hydrological responses [6] [16] [17]. Elevation and slope maps derived from DEMs further inform terrain suitability for water retention and flood control [7] [15]. LULC classification, performed through supervised methods like random forest algorithms, is validated via ground-truthing to ensure accuracy [7] [18].

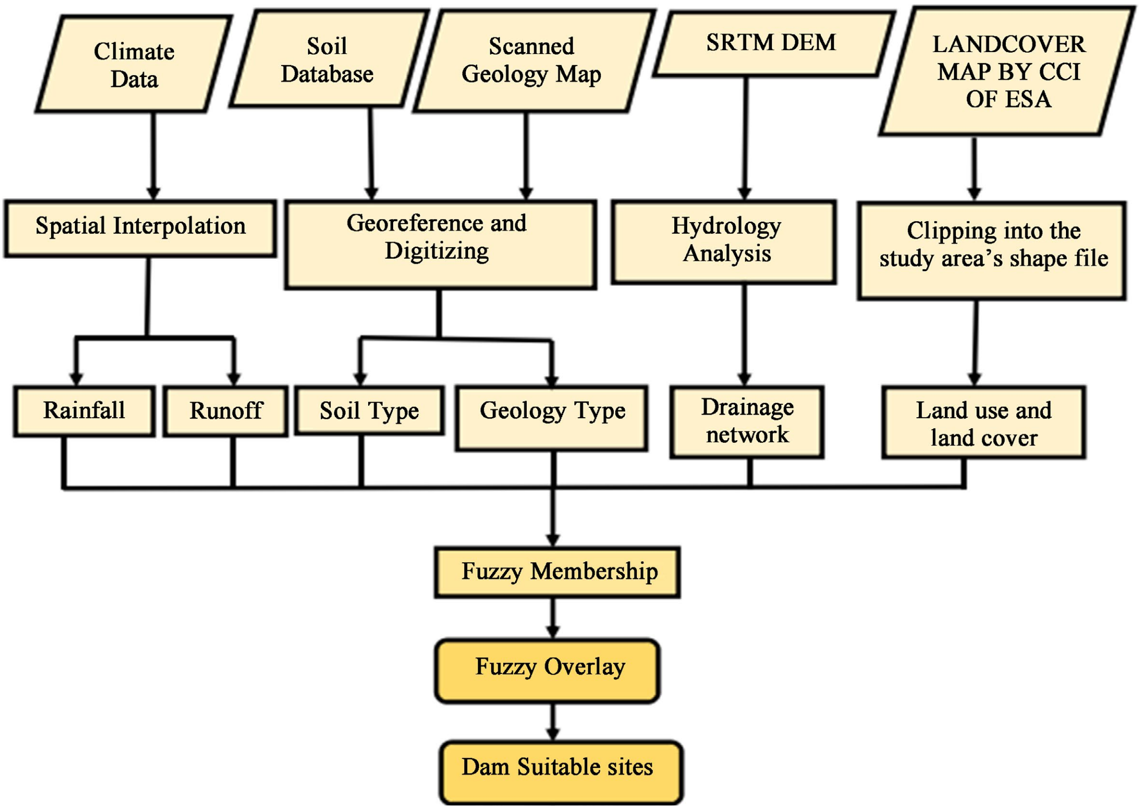

Figure 2. Methodology flow diagram.

This approach employs GIS and remote sensing tools (e.g., ArcGIS, Raster libraries) to synthesize spatial data, enabling multi-criteria decision analysis (MCDA) frameworks such as the Analytic Hierarchy Process (AHP) to weight and overlay thematic layers [7] [9] [15]. For instance, studies in hilly regions of China and semi-arid watersheds in Ethiopia demonstrate how machine learning and GIS integration optimize land consolidation and crop suitability assessments, aligning with dam siting priorities [9] [18]. Hardware tools, including high-performance computing systems and GPS devices, support data collection and processing, while software like Microsoft Excel facilitates statistical analysis and visualization [7] [18].

The integration of these layers in GIS highlights areas with optimal conditions for water retention and agricultural productivity, balancing environmental stability and hydrological efficiency [5] [15]. For example, dynamic CN datasets (e.g., CUSCN30) and global gridded CN products (e.g., GCN250) enhance runoff prediction accuracy, critical for flood risk assessment in dam planning [8] [14]. This systematic methodology ensures that selected dam sites align with sustainable development goals, as evidenced by applications in diverse regions such as Brazil's Guariroba basin and Turkey's Tekirdağ province [9] [17].

4. Result and Discussions

4.1. Dam Suitability Stream Model

In this study, the Dam Suitability Stream Model (DSSM) is developed as a streamlined approach for identifying suitable sites for dam construction, with a primary focus on optimizing locations to support agricultural productivity. The DSSM uses remote sensing (RS) and geographical information systems (GIS) technology to assess and integrate key environmental and hydrological parameters, especially focusing on stream order, which is a classification of river segments based on their hierarchy within a drainage network. This stream hierarchy is fundamental in identifying potential dam locations with adequate water availability, flow rates, and minimal environmental disruption.

Drainage Network and Stream Order: The stream order, based on Strahler's law, classifies rivers and tributaries by their hierarchical position within the watershed. This classification highlights areas with stronger water flow, suitable for potential dam construction. As depicted in **Figure 3**, the drainage network of the Owerri North is extracted through this method, facilitating targeted analysis on flow characteristics.

Slope Map: A slope map is generated from the DEM data using ArcGIS software. This slope layer is essential for identifying regions with varying inclinations, as slope stability and topography influence both dam construction feasibility and water retention potential. As seen in **Figure 4**, the slope is classified into five classes to ensure detailed assessment and analysis of the terrain.

Elevation Layer: DEM data serves as the primary elevation layer, which is similarly organized into five elevation classes as portrayed in **Figure 5**. This layered structure provides insights into altitudinal variations across the study area, further refining the suitability analysis by indicating optimal heights for water storage and minimizing overflow risks.

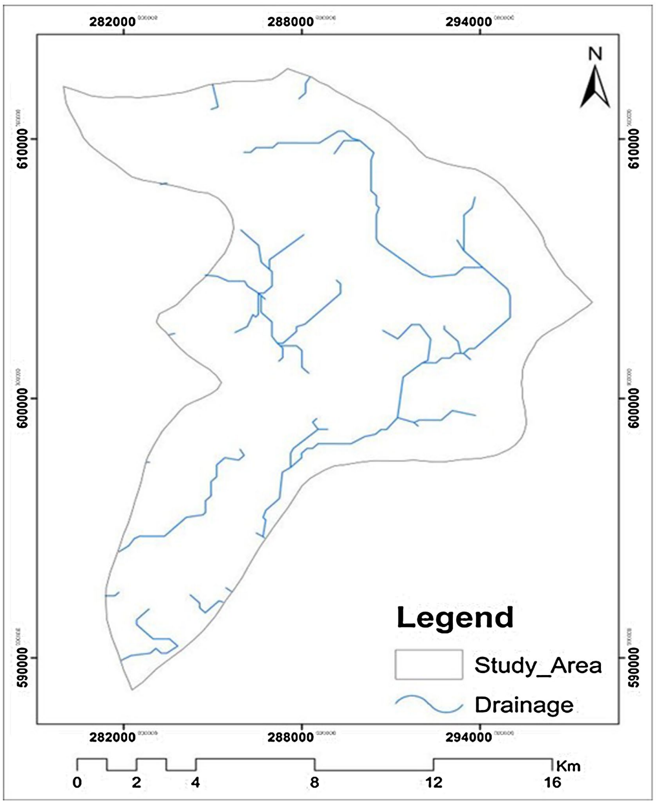

Figure 3. Drainage map.

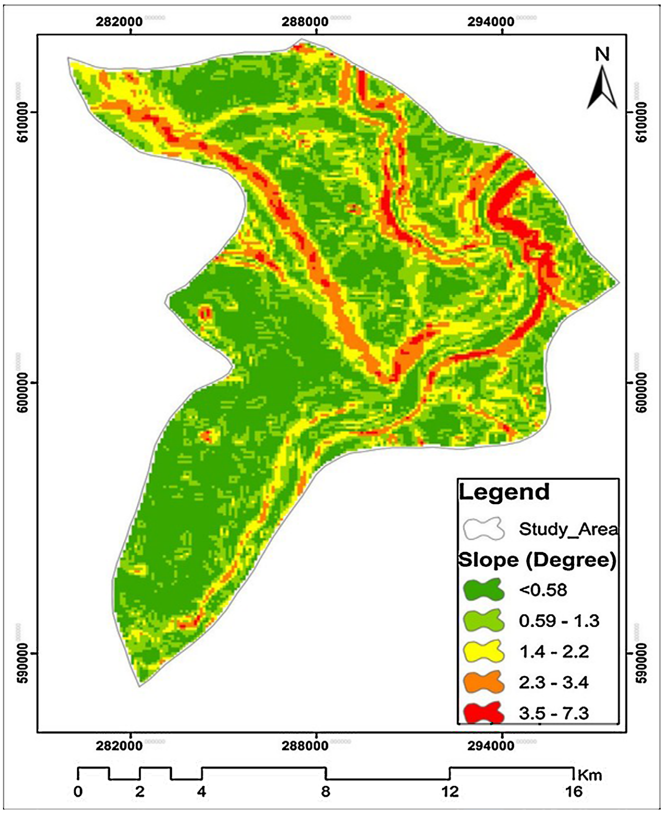

Figure 4. Slope map.

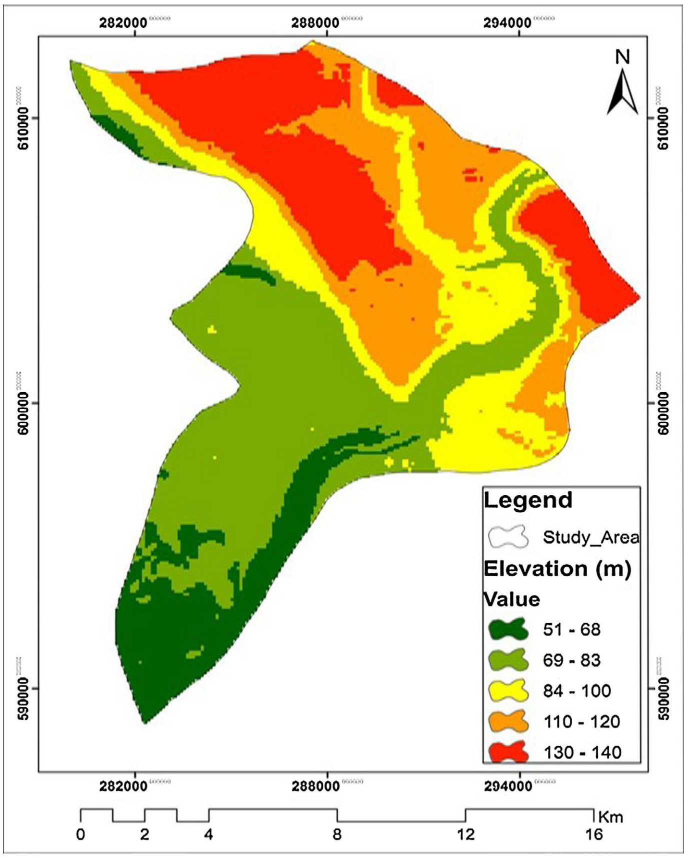

Figure 5. Elevation map.

Land Use/Land Cover (LULC) Classification: Figure 6 shows the result of a supervised image classification approach in ArcMap 10.8.2 software, which was used to create a comprehensive LULC map, categorizing the landscape into four classes: water bodies, Vegetation, Open Space, and Built Up. This LULC classification helps identify areas best suited for dam construction while minimizing disruptions to existing land uses, especially agricultural zones.

Geological Map: The geological structure of the study area is critical for assessing land stability and suitability for dam infrastructure. As shown in Figure 7, the geological map of the region is digitized and converted into raster layers, which are later integrated into the DSSM. This layer ensures that dam construction sites are evaluated for their geological compatibility.

Euclidean Distance Zones: To enhance the stream order analysis, the Euclidean Distance tool in ArcGIS is used to create distance zones from the primary streams. The output is shown in Figure 8(a). This distance-based layer acts as a "reciprocal parameter" to stream order by providing a nuanced understanding of spatial proximity to water sources. By substituting the Euclidean distance layer for stream order in certain analyses, we gain additional flexibility in determining optimal locations based on accessibility to water flow while minimizing interference with local landscapes.

Each criterion layer is developed based on an extensive review of relevant

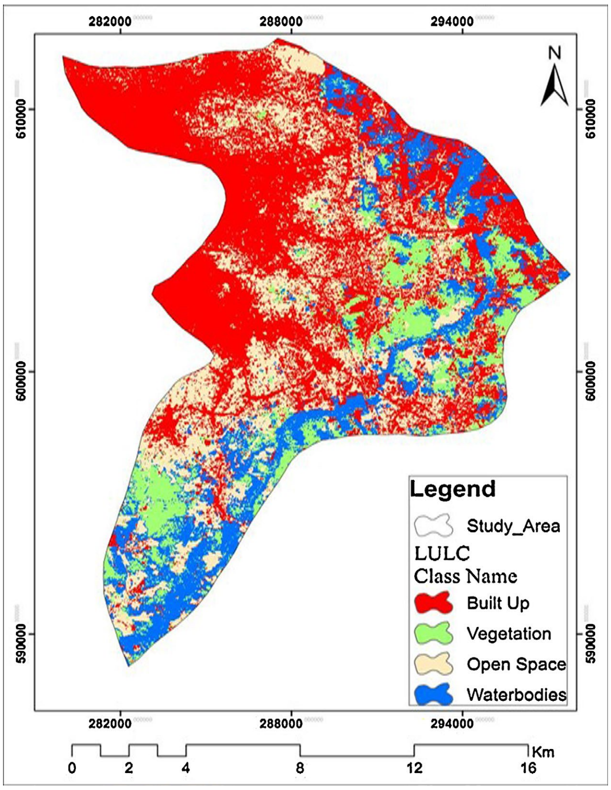

Figure 6. Landuse/Landcover map.

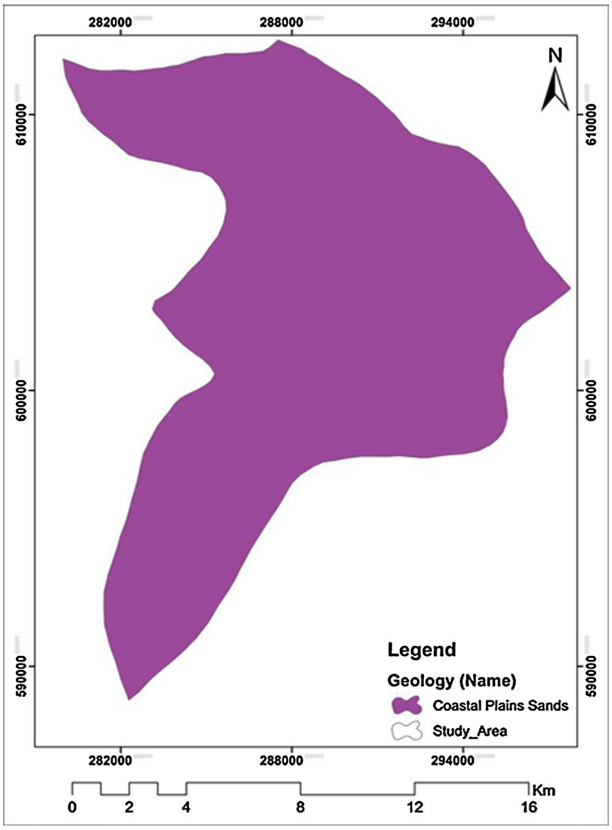

Figure 7. Geologic map.

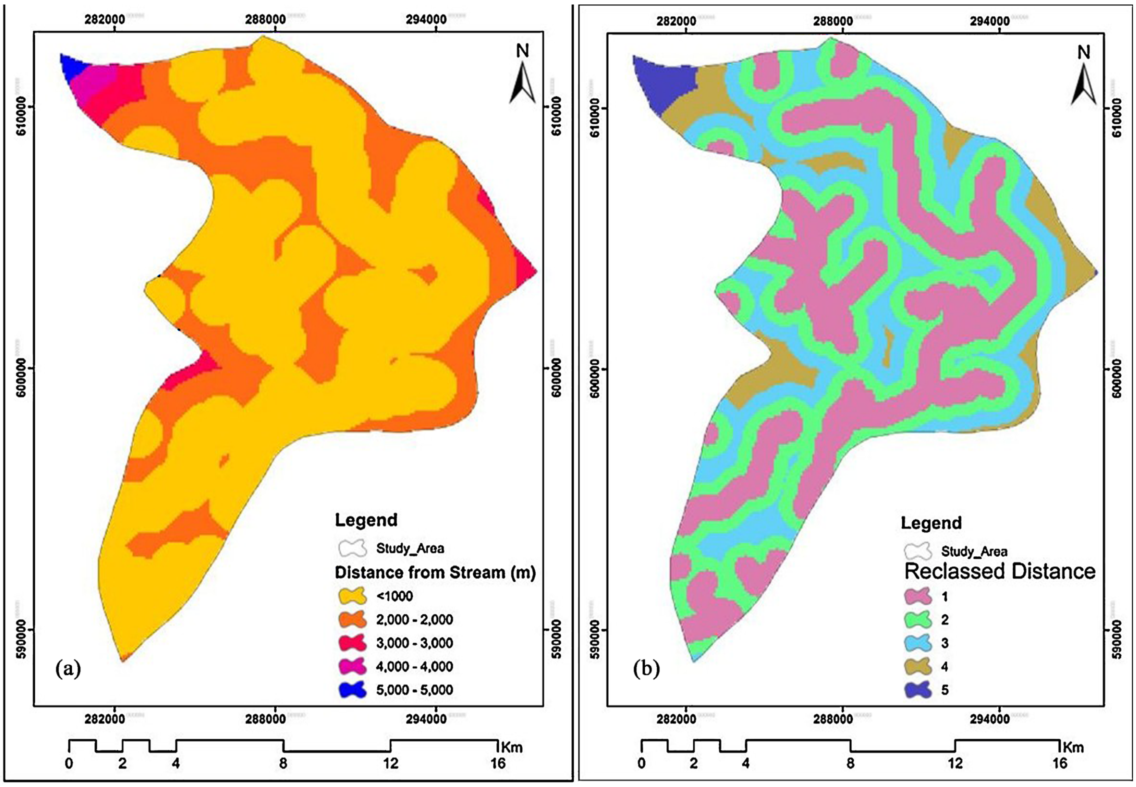

Figure 8. Reciprocal parameter of stream order or Euclidean distance (a) distance from the streams (b)reclassified raster layer.

literature and the input of experts in fields such as geology, GIS, and geography. These layers serve as the foundation for further analysis, classification, and reclassification stages in the DSSM, ensuring a robust, multi-dimensional approach to selecting optimal dam sites. The use of the Euclidean distance tool and additional GIS functionalities refines our understanding of spatial relationships within the watershed, making it possible to propose dam sites that are both feasible for construction and beneficial for agriculture.

4.2. Reclassification

The reclassification process in the Dam Suitability Stream Model (DSSM) involves organizing raster criteria layers into standardized classes to support streamlined, comparative analysis of potential dam sites. Using the reclassification tool in ArcGIS, each raster layer is restructured into four distinct suitability classes, providing a consistent classification across parameters. This step enhances the precision of site selection by aligning diverse data into a unified framework.

An exception to the four-class system is made for the geological layer, which is classified into three categories based on expert opinions, including input from geologists, GIS specialists, and environmental scientists. This three-category system for geology allows a more tailored approach to evaluate land stability, composition, and structural integrity, which are vital for dam safety and longevity. The reclassified layers collectively represent a multi-criteria suitability profile for dam site selection, as outlined in **Table 1**. These categories help in identifying locations that align with the physical, environmental, and logistical requirements for dam construction, ultimately enhancing the reliability of the DSSM's recommendations. The reclassified raster layer map is shown in **Figure 8(b)**.

Table 1. Reclassified layers and their preference value.

S/N	Criteria	Classes	Preference Value	Suitability
1	Stream order	1^{ST} Order	1	Least
		2^{nd} order	2	Moderate
		3^{rd} order	3	High
	Euclidean distance or Buffered streams (m)	<1000	5	High
		500 - 1000	4	Moderate
		1000 - 1500	3	Less
		1500 - 3000	2	Low
		>4000	1	Very Low
2	Slope (degree)	<0.58	5	High
		0.59 - 1.3	4	Moderate
		1.4 - 2.2	3	Less
		2.3 - 3.4	2	Low
		>7	1	Very Low
3	Digital Elevation Model (m)	51 - 68	5	High
		69 - 83	4	Moderate
		84 - 100	3	Less
		110 - 120	2	Low
		<51 >120	1	Very Low
4	Land cover	Built Up	1	Very low
		Vegetation	2	Low
		Open Space	5	High
		Waterbodies	4	Moderate
5	Geology	Coastal Plains Sands	4	Moderate

The Maps of stream order, reclassified slope, reclassified LULC, reclassified stream order and reclassified DEM are shown in **Figures 9-13**, respectively.

4.3. Rainfall and Discharge Data

To ensure the selected dam sites have adequate water availability throughout the year, the Dam Suitability Stream Model (DSSM) incorporates an analysis of long-term rainfall and discharge data. For this study, average monthly rainfall data

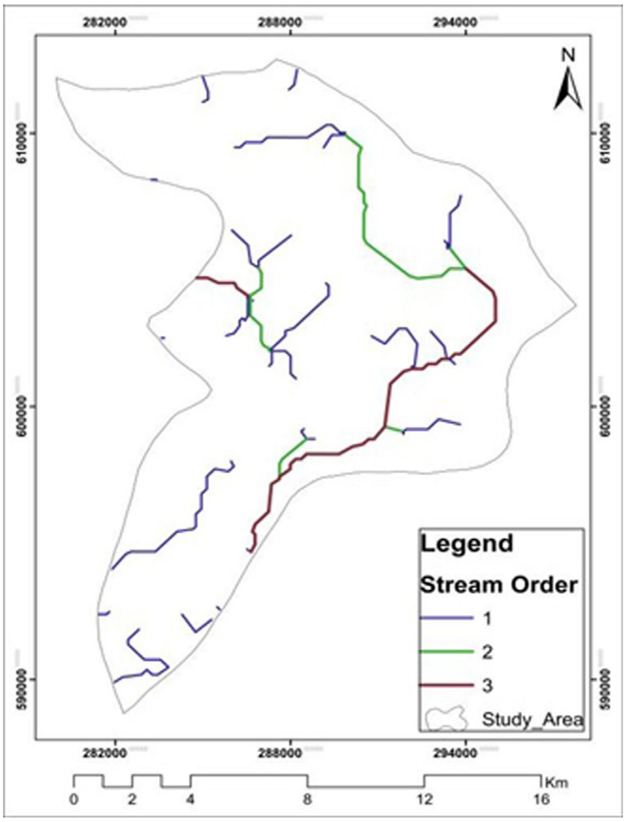

Figure 9. Stream order.

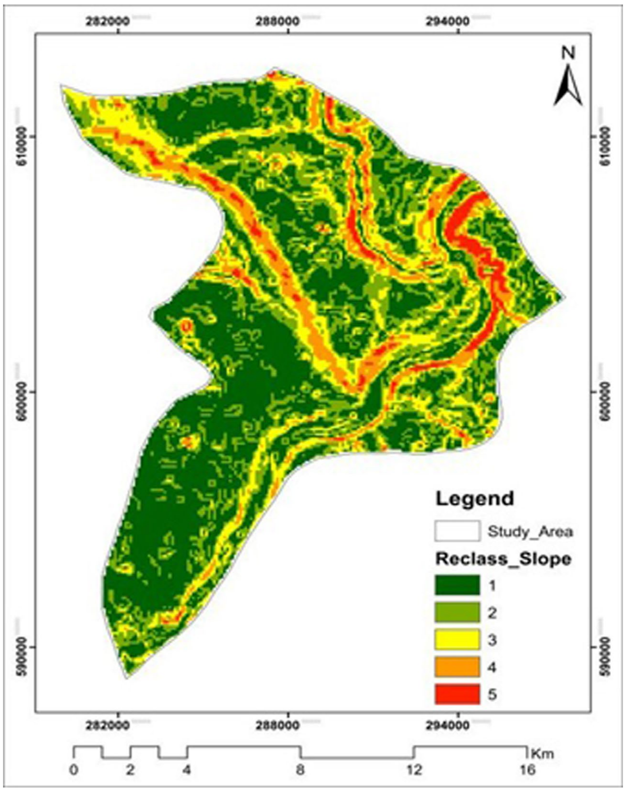

Figure 10. Reclass slope.

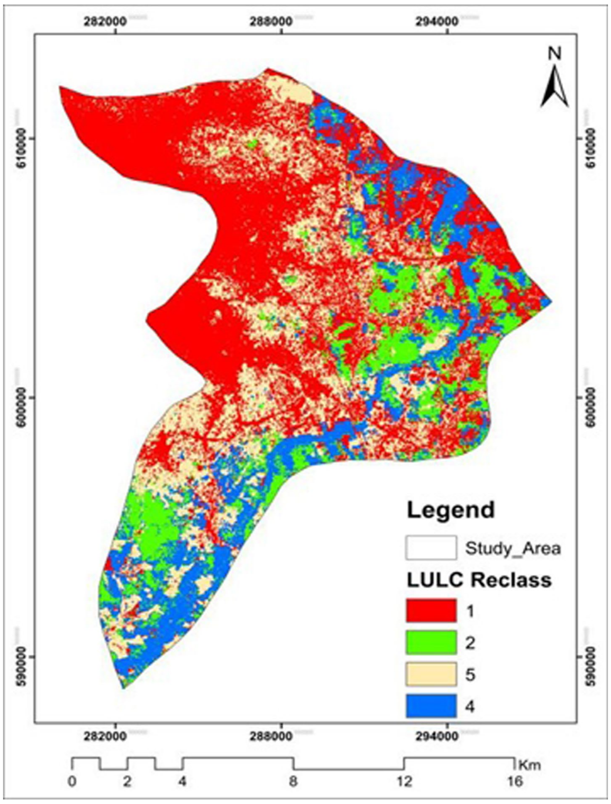

Figure 11. Reclass LULC.

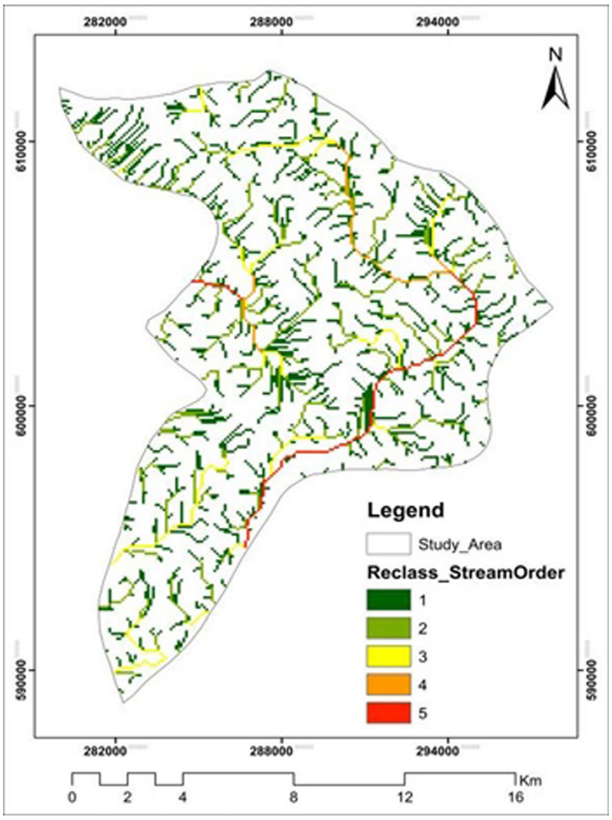

Figure 12. Reclass stream order.

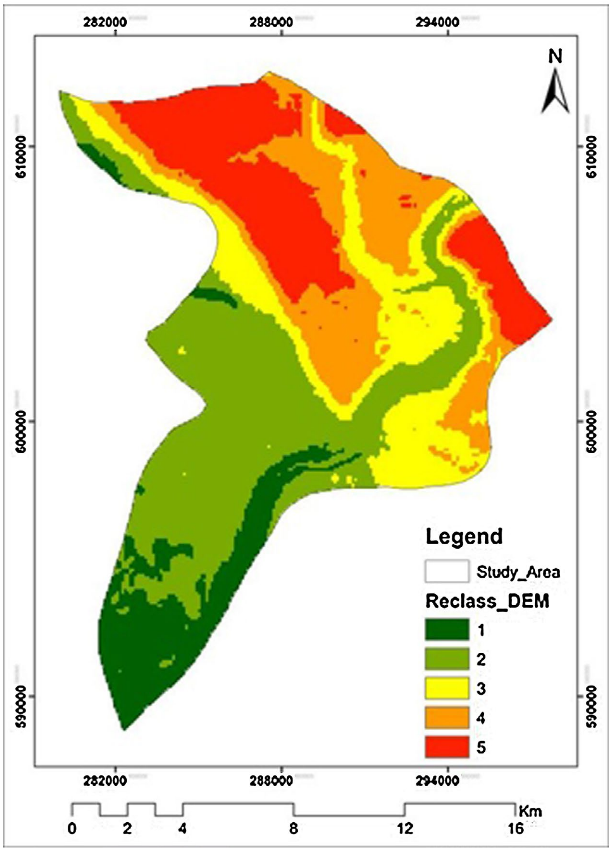

Figure 13. Reclass DEM.

spanning from 1990 to 2024 is examined, providing a comprehensive 34-year perspective on precipitation trends. This historical rainfall data is sourced from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), accessed via Climate Engine, which integrates satellite data and in-situ measurements for enhanced accuracy. Daily CHIRPS data are averaged to derive monthly values, enabling us to understand seasonal variations and overall rainfall trends within the study area. Analyzing this data allows us to estimate the water inflow potential at proposed dam sites, ensuring that chosen locations can sustain water levels needed for agricultural irrigation and other downstream needs.

Incorporating this data ensures that selected dam sites are hydrologically sound and capable of providing reliable water resources, directly benefiting agricultural productivity and supporting water resource management goals within the region.

4.4. Analytic Hierarchy Process (AHP) Analysis

The Analytic Hierarchy Process (AHP) is used in this study as a robust weighting method within the GIS-based Multi-Criteria Decision Making (MCDM) framework to evaluate dam site suitability. AHP is particularly effective for structuring complex decision-making processes, allowing for the systematic comparison of multiple criteria. This approach enables the assignment of weighted values to each criterion, based on their relative importance for selecting optimal dam sites.

Table 2. Saaty's pairwise comparison scale.

Intensity of Importance/Judgments	Numeric Value
Equal importance	1
Equal to moderate importance	2
Moderate importance	3
Moderate to strong importance	4
Strong importance	5
Strong to very strong importance	6
Very strong importance	7
Very strong to extremely strong importance	8
Extreme importance	9

For the multi-purpose dam site suitability analysis in this study (see Figure 9), AHP follows a structured five-step methodology:

Pairwise Comparison of Criteria: Using expert opinions, a pairwise comparison of criteria is conducted. This involves comparing each criterion against others in terms of importance, using a fundamental scale (shown in Table 2). This comparison considers factors such as hydrology, topography, land use, geology, and proximity to agricultural land.

	Stream Order	**Slope**	**DEM**	**Land Use**	**Geology**
Stream Order	1	3	5	7	2
Slope	0.333333333	1	4	6	3
DEM	0.2	0.25	1	3	2
Land Use	0.142857143	0.166666667	0.333333333	1	0.5
Geology	0.5	0.333333333	0.5	2	1
Sum	2.176190476	4.75	10.83333333	19	8.5

Normalization of Preference Matrix: To ensure consistency in weighting, the preference matrix is normalized, transforming each criterion's importance rating into a proportional scale. This normalized matrix standardizes the data, facilitating accurate weight calculation. (See Table 3)

Table 3. Normalize matrix.

	Stream Order	**Slope**	**DEM**	**Land Use**	**Geology**	**Average**	**Weight**
Stream Order	0.4595186	0.631578947	0.461538462	0.368421053	0.235294118	0.431270236	43
Slope	0.153172867	0.210526316	0.369230769	0.315789474	0.352941176	0.28033212	28
DEM	0.09190372	0.052631579	0.092307692	0.157894737	0.235294118	0.126006369	12
Land_Use	0.065645514	0.035087719	0.030769231	0.052631579	0.058823529	0.048591515	5
Geology	0.2297593	0.070175439	0.046153846	0.105263158	0.117647059	0.11379976	12

Calculation of Consistency Ratio: A consistency ratio (CR) is calculated to verify the reliability of the pairwise comparisons. If the CR is below a threshold (typically 0.1), the comparisons are considered consistent; otherwise, adjustments are made to improve alignment. This step ensures that the weighting process is both logical and statistically sound.

CR = CI/RI

Consistency Index (CI)	Consistency Ratio (CR)
0.094412286	0.084296684

The final outcome of the AHP analysis is a set of weighted criteria, with each criterion's weight reflecting its significance in the context of dam suitability. These weights are then applied in the overlay analysis, guiding the model to prioritize areas that best satisfy the multi-purpose dam requirements. This systematic and quantitative approach enhances the reliability of the DSSM, ensuring that selected dam sites align with both agricultural needs and environmental sustainability.

4.5. Overlay Analysis

The overlay analysis in the Dam Suitability Stream Model (DSSM) is a key step that integrates all reclassified and weighted criterion layers to create a comprehensive suitability map. This process is carried out using the weighted overlay tool in ArcGIS, which combines spatial data with calculated weights to assess the suitability of various locations for dam construction. The weights assigned to each criterion are derived from previous analyse and are set in the tool's "scale value" and "influence%" fields, ensuring that the most influential factors are appropriately prioritized.

Each raster layer, standardized to a 30 m × 30 m spatial resolution, is input into the overlay tool. Two main approaches are taken in this analysis to explore the influence of stream order and proximity:

Direct Stream Order Inclusion: In the first overlay analysis, stream order is directly included as a primary factor, providing a clear representation of areas with strong flow and water availability, which are essential for dam suitability.

Euclidean Distance as Stream Order Reciprocal: In the second approach, a Euclidean distance layer is used in place of stream order. This distance-based layer, derived from proximity zones around streams, acts as a "reciprocal parameter" and provides an alternate perspective by focusing on accessibility to streams while minimizing the impact on the stream network itself. This dual approach offers a more balanced analysis, catering to both hydrological efficiency and spatial considerations.

The weighted overlay process results in a suitability map that highlights optimal areas for dam placement, aligning with the criteria hierarchy established in the AHP analysis.

Proposed Dam Sites and Evaluation: Following the overlay analysis, the proposed dam sites are evaluated through a comprehensive assessment of their physical and hydrological characteristics. Nine critical parameters are considered to determine each site's feasibility and suitability. The 3D surface area is calculated to understand the spatial extent of the water surface, while the 2D surface area represents the planimetric (flat) area, aiding in storage capacity comparisons relative to land use impact. Maximum volume estimates the water storage potential, which is crucial for supporting agricultural water supply. The base and surface elevations are analyzed to provide insights into the dam's height and potential energy storage capacity. Structural stability and water retention are assessed through the dam's height and width, while the catchment area, identified using hydrological tools, indicates the watershed size contributing to each site and directly affects water availability. Contour closeness, derived from a 10 m interval digital elevation model (DEM), provides information on slope steepness, which is essential for evaluating topographical suitability, stability, and water flow dynamics.

A triangulated irregular network (TIN) created from contour data offers a 3D model that facilitates the calculation of the dam's surface area and volume. Additionally, the 3D Analyst tool in ArcGIS generates cross-sections of the proposed dam profiles, visualizing height and width to illustrate their spatial distribution. This integration of spatial and hydrological analysis tools ensures a thorough evaluation of each proposed dam site, verifying that they meet both technical and agricultural suitability requirements.

Suitability Maps and Stream Importance

The analysis results produce two distinct suitability maps for potential dam sites, providing complementary perspectives on site viability. These maps are classified into three suitability categories: High, Moderate, and Least Suitable. Each category reflects the degree to which locations meet the model's criteria for dam construction, based on water flow, accessibility, and other weighted parameters.

Suitability on Stream Map: As seen in Figure 14, this map focuses specifically on areas in close proximity to stream networks, highlighting sites where water availability from the stream is high. Locations classified as "High" suitability here indicate areas with strong stream flow, making them ideal for maximizing water retention and agricultural irrigation support.

Overall Suitability Map: The overall suitability map incorporates broader environmental and logistical factors beyond stream adjacency. This map integrates land use, topography, and geological data, providing a comprehensive view of suitable dam sites. As shown in Figure 15, "High" suitability areas on this map represent locations that balance water accessibility with optimal terrain, geological stability, and minimal disruption to existing land uses.

Multi-Purpose Proposed Dam Sites

This study generated two dam suitability maps **Suitability on Stream** and **Overall Suitability** each providing distinct insights into potential dam site locations based on differing analytical approaches. Both maps classify sites into three

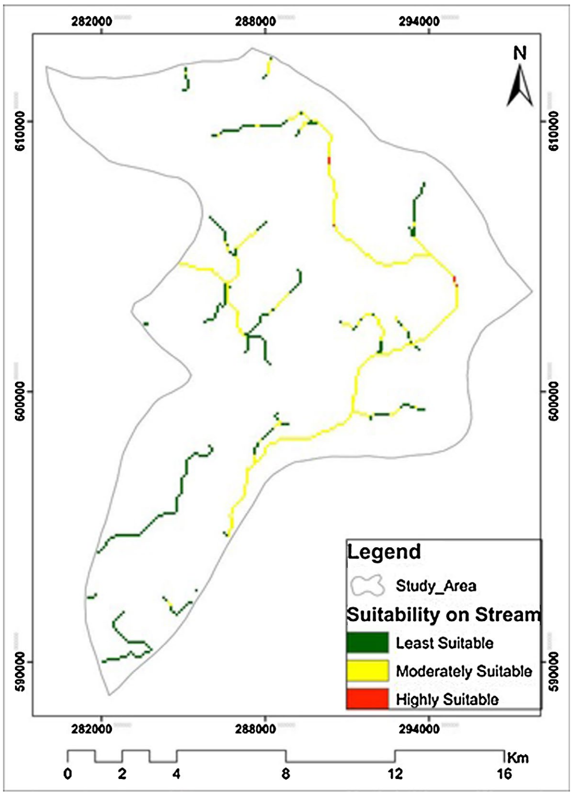

Figure 14. Suitability on stream.

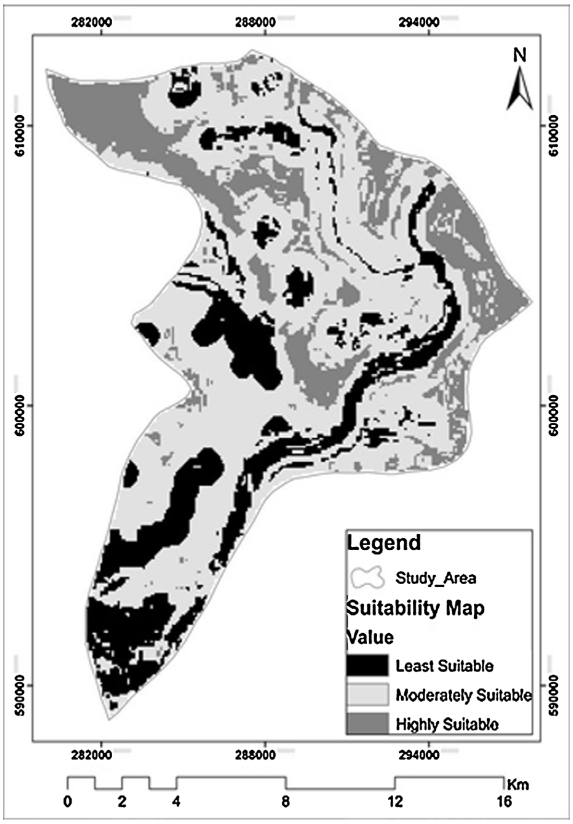

Figure 15. Suitability map.

suitability categories: High, Moderate, and Least Suitable. However, the focus and criteria weighting vary, leading to different emphases in site selection.

The Suitability on Stream map was developed by directly incorporating stream order as a primary factor, with the stream order raster layer set to a 30 m × 30 m resolution to match other layers. Given the highest weight, stream order prioritizes areas close to streams, ensuring that high-suitability pixels align with abundant water flow. The surrounding area's features such as slope, elevation, land use/land cover (LULC), and geology were also factored into the analysis, capturing both on-stream and adjacent areas with optimal conditions for dam construction. This map focuses on the lower reaches of the Owerri North, where fewer settlements and lower flood risks support multi-functional dam goals, such as agricultural irrigation, flood control, and hydropower generation. The proximity to streams in these lower areas directly addresses the critical water availability requirement for agriculture, making this map more favorable for identifying sites with reliable water access.

Conversely, the Overall Suitability map used Euclidean distance from streams as a reciprocal factor, reclassifying distance into four zones, with all other criteria held consistent. This approach allows the map to capture suitability across the entire study area, including regions not directly adjacent to streams. However, this broad perspective reveals high-suitability areas in the lower reaches, where stream order is low, meaning water availability may be insufficient for dam purposes. Although lower reaches may offer favorable terrain, they often contain denser settlements and higher flood risks, posing challenges for sustainable dam development.

In comparing these maps, the Suitability on Stream analysis presents a more practical and sustainable basis for dam site selection. By concentrating on locations with direct stream access, this approach ensures adequate water resources, minimizes environmental impacts, and supports agricultural productivity, flood mitigation, and energy generation goals. Meanwhile, the Overall Suitability map, while inclusive, identifies many sites that lack essential water supply, limiting their feasibility for dam construction.

Evaluation of Proposed Dam Sites

The proposed dam sites were evaluated based on the essential parameters outlined in **Table 1**, along with visual representations. **Table 4** provides specific values for these parameters for both sites. Site 1 is located on a larger, higher-order stream (stream order 3) with a more expansive catchment area than Site 2, which is on a stream of order 2. The larger catchment and higher stream order make Site 1 volumetrically superior and more suitable for water storage. This increased volume also makes Site 1 economically favorable for dam wall construction due to its potential to support a larger, more sustainable structure. For Dam 1, the maps of the catchment area, LULC, slope, elevation and Tin are shown in **Figures 16-20** respectively. While that of Dam 2 are represented in **Figures 21-25** respectively.

Table 4. Selected dam site evaluation.

S/N	Evaluation Parameters	Dam 1	Dam 2	Essential Parameters	Dam 1	Dam 2
1	3D Surface area (m^2)	2.659167	0.217994	Built Up	211.5 (15.01%)	125.82 (63.45%)
2	2D surface area (m^2)	0.000981	0.000127	Vegetation	357.3 (25.36%)	0
3	Max volume (m^3)	0.018251	0.001826	Open Space	217.44 (14.43%)	72.45 (36.54%)
4	Elevation of base (m)	55 - 103	69 - 90	Waterbodies	622.8 (44.20%)	0
5	Elevation of surface (m)	90	70	Stream order	4	3
6	Catchment area (km^2)	88	35	Slope(degree)	<7	<3
7	Contour closeness	High	Very High	Average Elevation (m)	3.2	1.72
8				Geological Stability	Moderate	Moderate

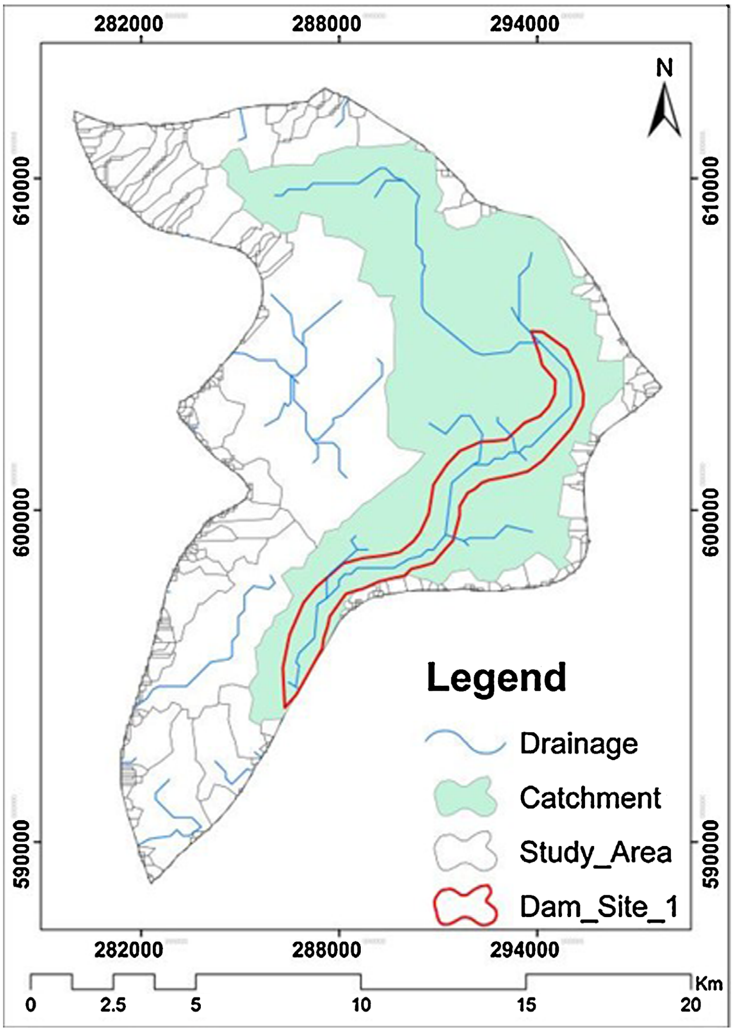

Figure 16. Catchement area for Dam 1.

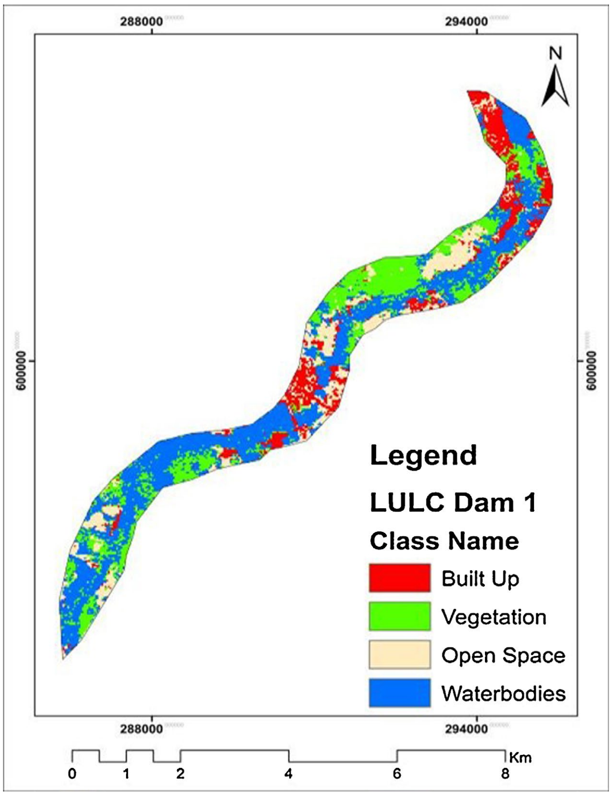

Figure 17. LULC area for Dam 1.

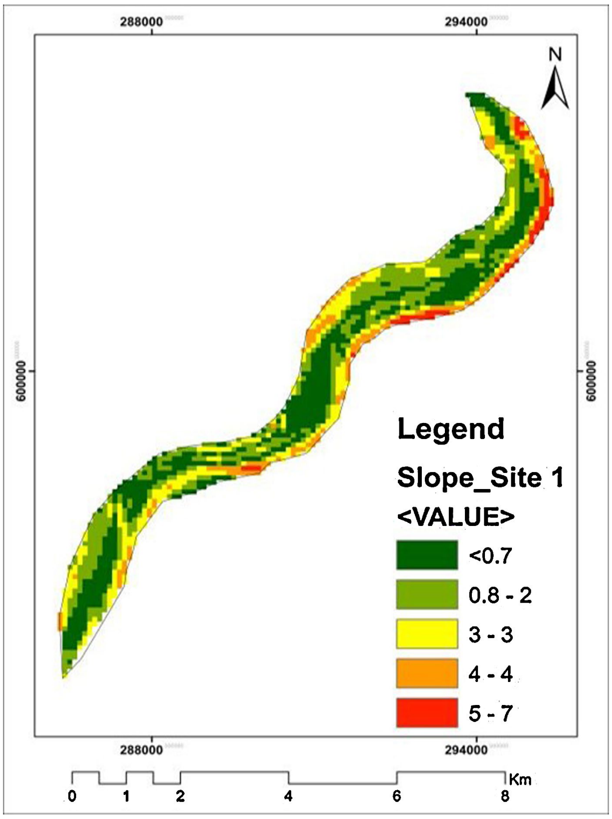

Figure 18. Slope(degree) for Dam 1.

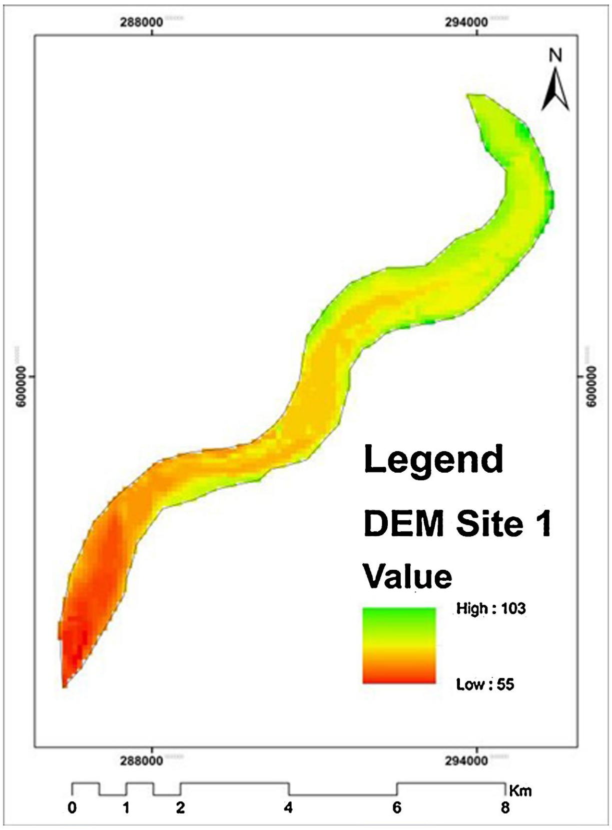

Figure 19. Elevation for Dam 1.

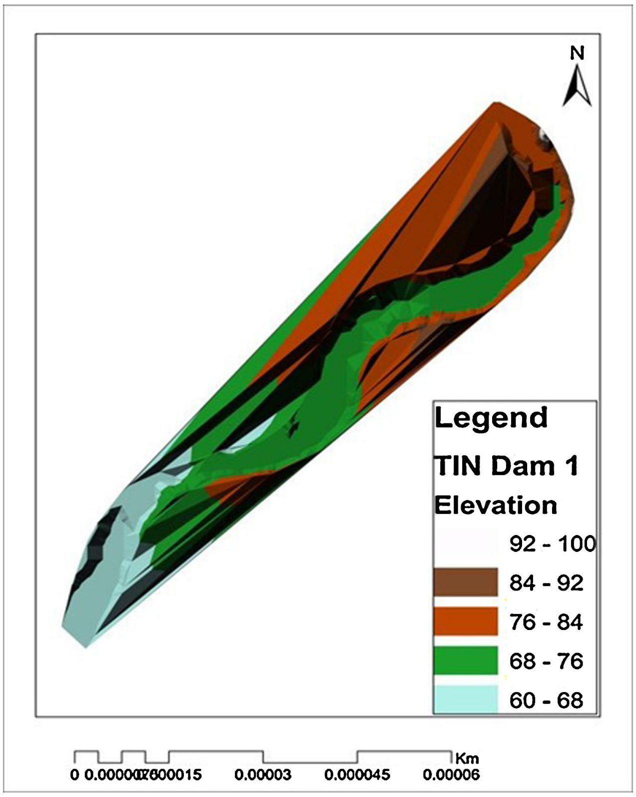

Figure 20. TIN for Dam 1.

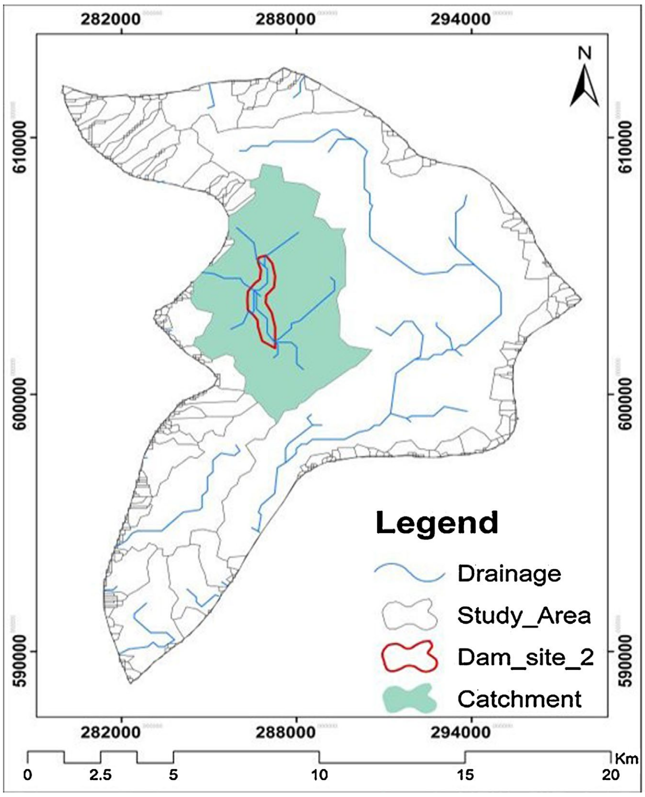

Figure 21. Catchment area for Dam 2.

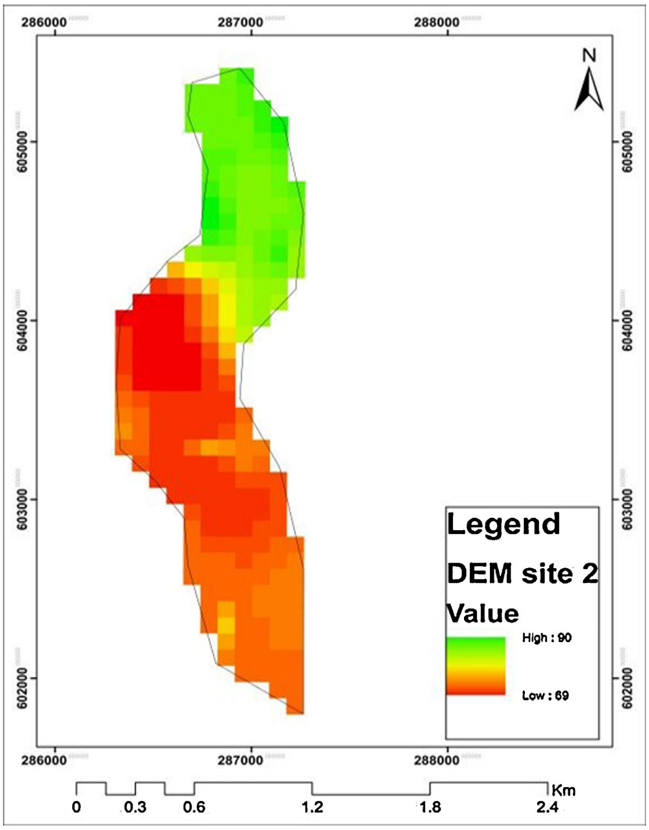

Figure 22. Elevation for Dam 2.

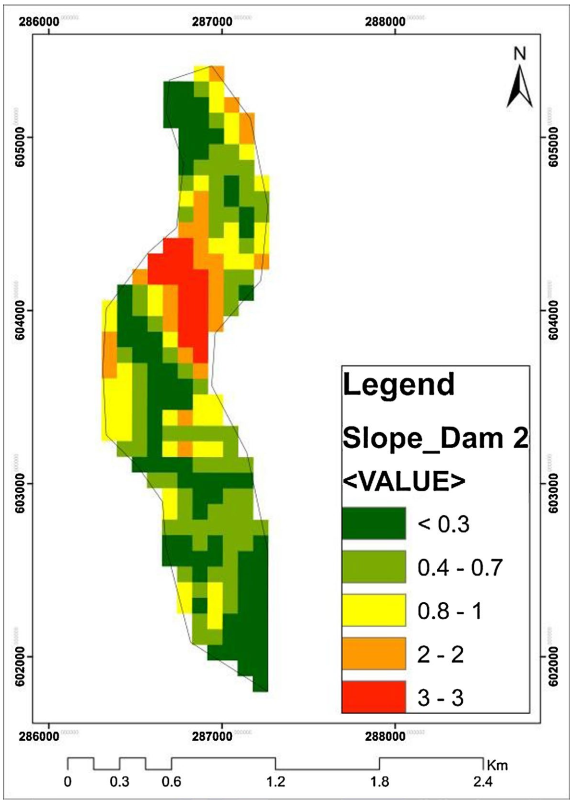

Figure 23. Slope(degree) for Dam 2.

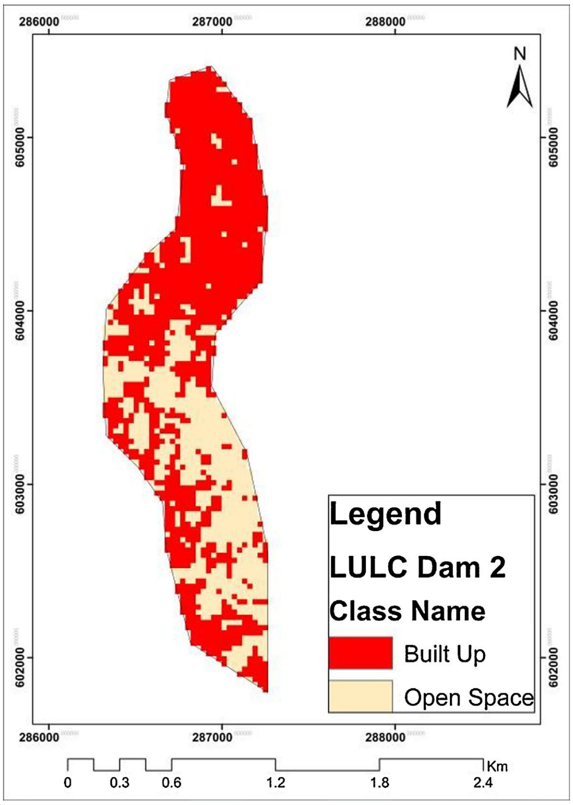

Figure 24. LULC for Dam 2.

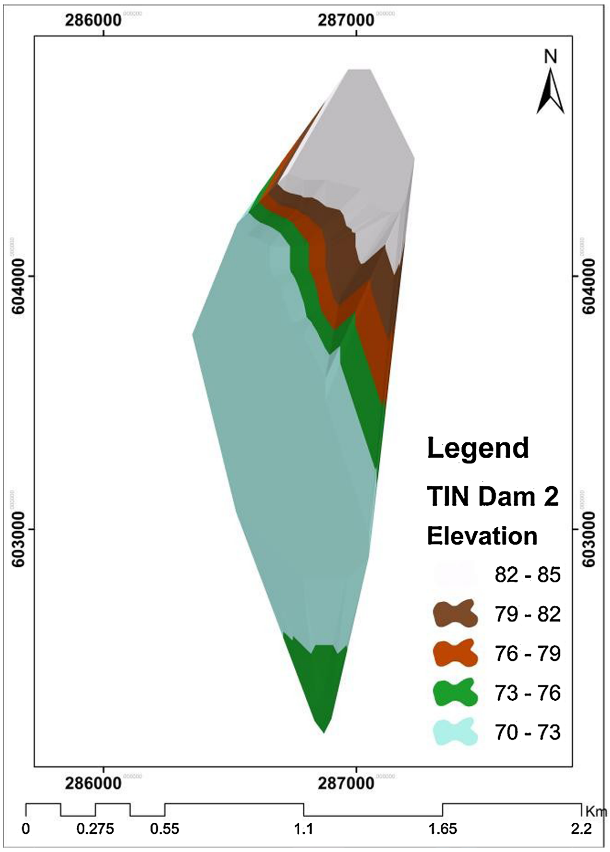

Figure 25. TIN for Dam 2.

5. Discussion

This study effectively employs the Dam Suitability Stream Model (DSSM), integrating Geographic Information Systems (GIS), Remote Sensing (RS), and the Analytic Hierarchy Process (AHP) to analyze topographical, geological, and hydrological data in Owerri North for dam suitability. By prioritizing stream order, land cover, and slope stability, the model provides a robust framework for identifying potential dam sites that could optimize agricultural water supply and environmental management. This comprehensive model produced two key suitability maps—Suitability on Stream and Overall Suitability—which offer distinct insights into site viability.

The Suitability on Stream map, focusing on high-order streams, prioritizes areas with abundant water flow and optimal topography for dam construction, particularly in the Lower reaches of Owerri North. This approach aligns well with agricultural needs, as high-order streams provide consistent water sources essential for irrigation, soil conservation, and flood control. In comparison, the Overall Suitability map, which integrates Euclidean distance from streams, broadens the scope to include areas across the landscape, including lower reaches. However, these areas present challenges such as lower stream orders, smaller catchment areas, and higher proximity to settlements, making them less feasible for sustainable dam projects. Evaluations of proposed sites underscore the advantages of prioritizing upper reaches: Dam Site 1, with a large catchment area and a third-order stream, is highly suitable for multipurpose use, including flood mitigation, irrigation, and potential hydropower. Such an approach not only serves agricultural productivity but also addresses community resilience by reducing risks of flooding and ensuring water availability. These findings indicate that DSSM, with its integration of environmental, hydrological, and spatial criteria, is a valuable tool for strategic dam site selection that aligns with agricultural and ecological needs.

6. Summary and Conclusion

The study concludes that the Dam Site Selection Model (DSSM) is a reliable and effective tool for identifying suitable locations for dam construction aimed at agricultural water management. By analyzing factors such as stream order, land cover, topography, and proximity to water sources, the model ensures that selected sites meet the dual objectives of water availability and environmental sustainability. Dam Site 1, situated on a high-order stream with significant catchment capacity, emerged as the most suitable location for multipurpose dam construction. The study highlights the importance of considering both water source reliability and environmental factors to address challenges like flood risks and inconsistent water supply, making DSSM adaptable for similar applications in other regions.

To maximize the benefits of dam infrastructure, the study recommends prioritizing high-order stream sites, implementing erosion control measures, and involving local communities in planning and development to align projects with community needs. Continuous monitoring of hydrological variables and adaptive management practices are essential to ensure a sustainable water supply amid climate variability. Encouraging water-efficient agricultural practices, such as drip irrigation, will further enhance productivity while conserving water resources. Future studies should incorporate advanced tools like high-resolution satellite data and machine learning to refine site selection processes and optimize agricultural water management strategies, laying a sustainable foundation for agricultural resilience and effective water resource management in Owerri North and similar regions.

Conflicts of Interest

The authors declare no conflicts of interest.

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