International Journal of Multidisciplinary Research and Growth Evaluation.

Developing a geographic information system (GIS)-driven model for assessing landscape suitability for water irrigation systems within NACEST environs in Benue State, Nigeria

Adebola Paul [1*], Sedi Peter [2]
[1] Nigerian Army College of Environmental Science and Technology (NACEST), Makurdi, Benue State, Nigeria
[2] Department of Surveying and Geoinformatics, Auchi Polytechnic, Auchi, Edo State, Nigeria

* Corresponding Author: **Adebola Paul**

Article Info

ISSN (online): 2582-7138
Volume: 05
Issue: 04
July-August 2024
Received: 25-05-2024;
Accepted: 29-06-2024
Page No: 663-671

Abstract
The overarching goal of this study was to develop a Geographic Information System (GIS)-driven model specifically tailored to assess landscape suitability for water irrigation systems in NACEST environs, Benue State, Nigeria. The primary objective is to identify areas within NACEST environs, Benue State that are most suitable for water irrigation. This involves a meticulous consideration of various factors, including soil type, topography, land use, climate, water availability, and proximity to water sources. The study employed GIS technology to create suitability maps that visually represent and prioritize areas for irrigation development. The study identified three distinct water irrigation suitability zones within the study area: high, moderate, and low. The high suitability zone encompasses 87.94 hectares, which is 10.83% of the total area. The moderate suitability zone spans 310.70 hectares, representing 38.29%, while the low suitability zone covers 412.69 hectares, accounting for 50.88% of the area. These findings offer a framework for optimizing irrigation strategies, enabling farmers and agricultural planners to improve crop yield and productivity by concentrating efforts on high and moderate suitability areas, thereby utilizing water resources more efficiently.

Keywords: geographic, NACEST, water, GIS

1. Introduction

Water, Water, a fundamental and replenishable resource, holds a crucial role in preserving human life and fostering a spectrum of human activities (Gleick, 2014) [18]. Its significance extends across a myriad of sectors, encompassing agriculture (FAO, 2017) [16], sanitation (WHO, 2018) [47], economic development (World Bank, 2016) [48], water storage (Keller *et al*., 2000), flood mitigation (UNEP, 2012) [45], irrigation (Postel, 1999) [42], power generation (IEA, 2015) [20], aquaculture (FAO, 2018) [17], fisheries (Allan *et al*., 2005) [8], and navigation (Pinter *et al*., 2016) [41]. While water resources bring myriad benefits, their utilization necessitates a careful balance to mitigate potential negative environmental and socio-economic impacts (Shiklomanov, 2000) [43].

The intricate distribution of water resources, both temporally and spatially, creates a complex scenario where certain regions grapple with simultaneous occurrences of flood and drought (Vörösmarty *et al*., 2000) [46]. This global challenge, underscored by Dai (2016) [13], presents obstacles that communities worldwide must navigate. In the context of Benue State, this complexity manifests as water scarcity, a fundamental issue exacerbated by the contemporary effects of global warming (IPCC, 2014) [21].

Benue State finds itself in a challenging predicament, relying on seasonal rivers that flow only after rainfall, rendering the land predominantly arid for a substantial portion of the year (Adeoye *et al*., 2009) [2]. Regrettably, these water sources often desiccate entirely, and when accessible, they tend to be tainted (Ufoegbune *et al*., 2011) [44]. Consequently, there is a dearth of fresh surface water in various parts of the state (Akintola, 1986) [7].

Although groundwater offers an alternative, its quantity and quality frequently fall short of meeting the escalating demands of the burgeoning population (Offodile, 2002) [27], perpetuating a cycle where demand persistently outstrips supply (Ojo *et al*., 2012) [30].

The ramifications of water scarcity in Benue State extend far beyond the immediate issue of water availability (Olorunfemi *et al*., 2007) [35]. The laborious quest for water consumes a significant portion of time, leaving scant room for other vital activities such as agriculture and education (Ajayi *et al*., 2013) [4]. Consequently, communities in the region contend with protracted water shortages, impeding their holistic development (Goni *et al*., 2015) [19].

Effectively addressing this pressing issue demands strategic interventions, and one proposed remedy is the construction of a robust reservoir (Nwankwoala, 2015) [25]. Such infrastructure could serve as a dependable and sustainable water source, meeting both current and future demands of the populace (Nzewi, 1989) [26]. Consistent water supply assumes particular importance for agricultural activities, given that drought remains a significant contributor to food scarcity (Orebiyi *et al*., 2010) [38]. The establishment of water supply and irrigation facilities becomes imperative to ensure a continuous food supply throughout the year (Ayoade, 1975) [9].

The challenges posed by water scarcity in Benue State emphasize the urgent need for comprehensive solutions (Ayoade, 1988) [10]. These solutions should not only tackle immediate water supply concerns but also contribute to the broader socio-economic development of the region (Onugba, 2018) [37]. The construction of resilient water infrastructure emerges as a proactive stride towards forging a sustainable and resilient future for the communities grappling with water scarcity in Benue State (Chukwuma, 1993) [12]. This endeavor encompasses a holistic approach, recognizing the interconnectedness of water availability, agricultural prosperity, and overall community well-being (Balogun, 2003) [11].

The pivotal role played by agriculture in contributing 24.18% to the country's Gross Domestic Product (GDP) not only solidifies its status as an economic driver but also underscores its critical importance to overall societal well-being (NBS, 2020) [23]. A comprehensive exploration of the agricultural sector becomes imperative, particularly when aiming for year-round production (Oni, 2018) [36]. Such endeavors not only positively impact the GDP but also elevate the standard of living for the population (Osinubi, 2003) [39]. Consistent agricultural productivity has the potential to lead to lower crop prices, benefiting consumers and fostering economic stability on a broader scale (Olomola, 2015) [33].

In the specific case of Benue State, the central focus of this study revolves around the pervasive issue of inadequate water supply in certain regions (Ezenwaji *et al*., 2014) [15]. Prior efforts, exemplified by Ufoegbune *et al*. (2011) [44], have addressed analogous challenges in different locales, taking into account factors like rainfall, land cover, and geology (Okechukwu *et al*., 2017) [31]. However, the persistent water supply problem in Benue State arises from the absence of an effective, efficient, and accurate method for site selection, a crucial component of comprehensive terrain investigation (Ofomata, 1975) [28]. The lack of a centralized water supply system further compounds the situation, compelling residents to procure water daily for both domestic and agricultural purposes (Nwafor, 2007) [24].

The distinctive topography of Benue State poses a complex challenge, necessitating a more nuanced and extensive study to comprehend and tackle water scarcity effectively (Oladipo, 1993) [32]. Unlike other regions, the state's topography is diverse, demanding a meticulous examination that surpasses the factors considered in prior studies (Aderamo, 2002) [3]. The absence of a centralized water supply system for farms adds an additional layer of complexity, highlighting the need for a detailed investigation into the topography and the consideration of additional factors that previous researchers may not have incorporated (Ajayi, 1987) [5].

During dry seasons, the adverse effects on plant survival and the ensuing challenges in securing water for domestic use further underscore the urgency of this study (Ojo, 1977) [29]. The study not only aims to assess the topography but also seeks to establish locations suitable for irrigation (Olorunfemi, 1983) [34]. This facet assumes paramount importance as it directly addresses the critical issue of water scarcity, essential for both human consumption and agricultural activities (Adeniyi, 1993) [1].

Using the combinations of the topography and considering a broader spectrum of factors, this research endeavours to contribute to the development of a sustainable solution for water supply challenges in Benue State (Ezeabasili, 2009) [14]. The identification of suitable locations for irrigation is anticipated to play a pivotal role in mitigating water scarcity issues, ensuring a more reliable and consistent water supply for both the populace and agricultural endeavours (Oyebande, 1973) [40]. In essence, this research strives to provide a robust foundation for strategic planning and design, with the overarching goal of fostering economic development, elevating living standards, and creating a more resilient agricultural sector in Benue State (Akanmu, 2011) [6].

2. Materials and Methods

2.1. Study Area

The Nigerian Army College of Environmental Science and Technology (NACEST) is located in Makurdi, the capital city of Benue State, Nigeria. Benue State, often referred to as the "Food Basket of the Nation," is situated in the North-Central region of Nigeria, covering an area of approximately 34,059 square kilometers. Makurdi lies at coordinates 7°44′N latitude and 8°32′E longitude, with an average elevation of about 104 meters above sea level.

Geographical Setting

Makurdi is characterized by a tropical climate, with distinct wet and dry seasons. The wet season typically spans from April to October, bringing substantial rainfall, which peaks between July and September. Annual rainfall averages between 1,200 mm and 1,500 mm. The dry season lasts from November to March, marked by the harmattan winds that bring dry and dusty conditions.

The terrain around NACEST is primarily flat to gently undulating, with the River Benue running through the city, serving as a significant hydrological feature. The river is not only crucial for irrigation and fishing but also plays a vital role in the region's transportation network.

Ecological and Environmental Characteristics

The vegetation in Makurdi and its environs is classified under the Guinea savanna belt, characterized by tall grasses and scattered trees. This savanna ecosystem supports diverse flora and fauna, contributing to the region's agricultural productivity. However, the area also faces environmental challenges such as soil erosion, deforestation, and seasonal flooding, which impact both the natural environment and human activities.

Socio-Economic Context

NACEST is strategically located in Makurdi, which is an important educational and administrative hub in Benue State. The college benefits from its proximity to major transportation routes, including road and rail networks that facilitate accessibility from various parts of the country. Makurdi's socio-economic landscape is predominantly agrarian, with a significant portion of the population engaged in farming, trading, and small-scale industries.

The presence of NACEST in this region highlights the Nigerian Army's commitment to advancing environmental science and technology education, focusing on sustainable development and environmental management practices. The college's programs aim to address the unique environmental challenges of the area, promoting innovative solutions and resilience against ecological threats.

2.2. Methodology

The data used in this research includes Sentinel-2 satellite imagery, ALOS PALSAR data, soil data, geology data, rainfall data, and ground validation data. The data acquisition process involved two main steps: obtaining primary datasets and acquiring secondary datasets.

Acquisition of Primary Datasets: Primary datasets were collected through field visits specific to this study, ensuring the collection of accurate and relevant data. GPS ground observations were conducted to validate and enhance the accuracy of the remote sensing data.

Acquisition of Secondary Datasets: Secondary datasets were sourced from existing repositories. Sentinel-2 and ALOS PALSAR data were obtained from the Open Access Hub (copernicus.eu), providing high-resolution satellite imagery and radar data essential for detailed analysis. Geology and soil data were accessed from the Food and Agriculture Organization's website (www.fao.org), offering comprehensive information on the geological and soil characteristics of the study area.

Image Pre-processing: Before conducting any analysis, initial processing of the collected data was necessary to ensure accuracy. This involved radiometric correction, which adjusts for differences in sensor response, and geometric correction, which removes distortions caused by Earth's rotation or other imaging conditions. The images were then transformed to a specific map projection system, UTM Zone 32 North, using ground control points (GCPs) to ensure precise geo-referencing. Additional steps included band combination, which merges different spectral bands to highlight specific features of interest, and image subsetting, which extracts relevant portions of the image for focused analysis.

ALOS PALSAR Processing: ALOS PALSAR provides a topographical model with elevation records of cells in a specific size. However, potential errors such as sunken areas not captured due to data inaccuracies or karst topography were corrected by filling sinks using ArcGIS 10.5 software. The corrected DEM data was then used to calculate elevation and slope, which served as key components in the suitability analysis.

Image Classification: Supervised classification techniques were applied using ArcGIS software. The Image Classification toolbar was utilized to create training samples and signature files, essential for accurate classification. The Maximum Likelihood Classification tool was the primary method employed, requiring the generation of a signature file that outlines the characteristics and statistics of different classes. This file was created by collecting training samples through the Image Classification toolbar.

Factor Classification: Reclassification and standardization of criteria were crucial for implementing the Analytical Hierarchy Process (AHP) and weighted linear combination model. Each cell value was standardized to a common measurement system, facilitating the effective combination of datasets with disparate units. This transformation allowed for a relative weighting scale, enabling comprehensive analysis across different criteria.

Development of the Pairwise Comparison Matrix: The pairwise comparison method, introduced involved three steps: developing a pairwise comparison matrix, computing weights by normalizing the matrix and calculating the average of each row, and ranking criteria options based on the computed weights. This method allowed for a systematic comparison of criteria, providing a robust framework for decision-making.

Analytical Hierarchy Process (AHP): AHP simplifies complex decision-making by reducing it to a series of pairwise comparisons and synthesizing the results. Both subjective and objective aspects of a decision were captured, assigning numerical values to each criterion to weigh benefits and risks. The AHP used a ratio matrix known as the Eigenvector method and a numerical scale from 1 to 9 to compare factors, ensuring a comprehensive evaluation of each criterion's relative importance.

Pairwise Comparison Matrix Formation: The pairwise comparison matrix was formed by inputting judgment values between factors, obtained from expert judgment based on Saaty's scale. These values reflected the relative importance of each factor compared to others, ensuring a consistent and reliable framework for analysis.

Computation of Criterion Weights: The computation involved summing the values in each column of the pairwise comparison matrix, normalizing each element by its column total, and averaging the elements in each row to estimate the relative weights of the criteria. The consistency ratio (CR) was used to check the reliability of the judgments, ensuring that the computed weights were within acceptable limits.

Estimation of the Consistency Ratio: The consistency ratio (CR) checked the reliability of judgments relative to random samples. If the CR value was less than 0.1, the judgments were considered consistent; if greater, the weights were deemed inconsistent and required reassessment.

Dataset Overlay: Following the determination of weights, the weighted criteria were combined and merged to produce a suitability index map. This map, reflecting the suitability of the study area for the intended analysis, was categorized into four levels: extremely high, high, moderate, and low suitability.

3. Results

3.1. Identification and Selection of Criteria

Selection of the criteria and factors for water irrigation suitability was achieved based on their theoretical relevance as documented in for water irrigation suitability, The following criteria (factors/constraints) (table 1) were used in this research.

Table 1: Criteria and Requirements for water irrigation suitability

Criteria	Requirement for Suitability
Rainfall	Adequate annual rainfall (e.g., >500 mm/year)
Basin	Located within a well-defined drainage basin
Flow Accumulation	High flow accumulation areas
Elevation	Optimal range (e.g., 0-500 meters above sea level)
Slope	Gentle slope (e.g., <5% gradient)
Geology	Permeable rock formations to allow water infiltration
Soil	Fertile and well-drained soils (e.g., loamy soil)

Based on the criteria selected (table 1), the data used for achieving the aim of the research were assembled.

Criteria Analysis

Rainfall: Adequate and consistent rainfall is crucial for irrigation as it replenishes surface and groundwater sources. Areas with higher annual rainfall ensure a more reliable water supply for irrigation needs, reducing dependency on artificial systems and mitigating the risk of water shortages.

Basin: A well-defined drainage basin aids in efficient collection and distribution of water. Basins act as natural catchments, directing water flow towards rivers, lakes, or reservoirs, which can be harnessed for irrigation purposes. Proper basin management ensures sustainable water availability and reduces the risk of waterlogging and flooding.

Flow Accumulation: Areas with high flow accumulation indicate regions where water naturally converges, making them ideal for capturing and storing water for irrigation. These areas are often key locations for constructing reservoirs or ponds, ensuring a steady supply of water during dry periods.

Elevation: Optimal elevation ranges are important for irrigation as they influence water pressure and flow. Lower elevations generally have easier access to surface water sources and are less prone to water scarcity. Additionally, areas at moderate elevations can benefit from gravitational water flow, reducing the need for pumping and associated energy costs.

Slope: Gentle slopes (e.g., less than 5% gradient) are preferable for irrigation as they minimize runoff and soil erosion while maximizing water retention in the soil. Steep slopes can lead to rapid water loss and increased erosion, making them less suitable for efficient irrigation.

Geology: The geological characteristics of an area impact water infiltration and storage. Permeable rock formations, such as sandstone or limestone, allow for better groundwater recharge and storage, which can be tapped for irrigation. Conversely, impermeable rocks may hinder water movement and limit available water resources.

Soil: Fertile and well-drained soils, such as loamy soils, are ideal for irrigation as they retain sufficient moisture while allowing excess water to drain away, preventing waterlogging. Soil fertility is crucial for crop growth, ensuring that irrigation efforts lead to productive agricultural yields.

3.2. Reclassification and Standardization of Criteria

Reclassification and standardization of criteria is the first step in implementing the Analytical Hierarchy Process (AHP) and the weighted linear combination model. Different units of measurement need to be standardized to a common scale to combine datasets effectively. Each dataset was reclassified into three classes: high suitability, moderate suitability, and low suitability areas. The initially derived values were continuous and needed reclassification to discrete integer values such as 1, 2, and 3 according to the measurement scale. This standardization allows for effective analysis between datasets. The reclassified and standardized criteria are shown in table 2.

Table 2: Criteria and Requirements for water irrigation suitability

Criteria	Suitability Rank Value	Ranking
Rainfall	> 500mm	3
	< 1000mm	2
	< 1500mm	1
Basin	500	3
	1000	2
	2000	1
Flow Accumulation	> 1000	3
	< 2000	2
	< 2500	1
Elevation	98m – 140m	3
	77m – 98m	2
	64m – 77m	1
Slope	5% - 13%	3
	3% - 5%	2
	1% - 3%	1
Geology	Clay, Shale	3
	Limestone	2
	Sandstone	1
Soil	Sandy, Heavy Clay	3
	Clayey Loamy	2
	Loamy Soil	1

3.3. Analytical Hierarchy Process and Determination of Criteria Weight

The Analytical Hierarchy Process (AHP) simplifies complex decision-making by reducing it to a series of pairwise comparisons and synthesizing the results. It captures both subjective and objective aspects of a decision, assigning numerical values to each criterion based on their relative importance. AHP uses a ratio matrix, known as the Eigenvector method, and a numerical scale from 1 to 9, where 1 means equal importance and 9 means one factor is absolutely more important than the other.

Table 3: Relative Importance in Pairwise Comparison

Judgment value	Description
1	Equal importance
3	Moderately importance
5	Strongly Importance
7	Very strongly important
9	Extremely important

3.3.1. Pairwise Comparison Matrix Formation

The pairwise comparison matrix was formed by inputting judgment values between factors as matrix elements based on Saaty's scale.

Table 4: Pair-wise comparison matrix for water irrigation suitability

Criterion	Rainfall	Basin	Flow Acc.	Elevation	Slope	Geology	Soil
Rainfall	1	2	3	4	5	5	9
Basin	0.5	1	3	5	6	6	7
Flow Accumulation	0.33	0.33	1	5	6	6	7
Elevation	0.25	0.2	0.16	1	2	3	4
Slope	0.2	0.16	0.16	0.5	`1	2	3
Geology	0.2	0.16	0.16	0.33	0.5	1	4
Soil	0.11	0.14	0.14	0.25	0.33	0.25	1
Total	2.59	4.0	11.5	16	20.8	23.25	35

3.3.2. Computation of the Criterion Weights

The computation of criteria weights involved finding the sum of the values in each column of the pairwise comparison matrix, dividing each element by its column total (normalized pairwise comparison matrix), and computing the average of elements in each row to estimate the relative weights of the criteria.

3.3.3. Normalized Pairwise Comparison Matrix

Table 4.5 shows the normalized pairwise comparison matries that were formed. For example, to get the element of the normalized matrix of rainfall (row) against rainfall column i.e. matrix element in 1, 1, where 2.59 and 1 from the pairwise comparison matrix is the sum of the element of the second column and the judgment value of rainfall (row) against rainfall (column), therefore, normalized F1, F1 = (1/2.59) = 0.39 as shown in the table 5.

Table 5: Normalized Pairwise Comparison Matrix for water irrigation suitability

Criterion	Rainfall	Basin	Flow Acc.	Elevation	Slope	Geology	Soil	Mean
Rainfall	0.39	0.50	0.39	0.25	0.25	0.22	0.26	0.32
Basin	0.19	0.25	0.39	0.31	0.30	0.26	0.20	0.27
Flow Accumulation	0.13	0.08	0.13	0.31	0.30	0.26	0.20	0.20
Elevation	0.10	0.05	0.02	0.06	0.10	0.13	0.11	0.08
Slope	0.08	0.04	0.02	0.03	0.05	0.09	0.09	0.06
Geology	0.08	0.04	0.02	0.02	0.03	0.04	0.11	0.05
Soil	0.04	0.04	0.02	0.02	0.02	0.01	0.03	0.02

3.3.4. Prioritization weight matrix

In computing the element of this matrix, the normalized sum of each row is divided by the total number of its criteria. The obtained averages provide an estimate of the relative weights of the criteria being compared. For instance, the criteria weight of windspeed as a factor can be obtained thus;
Rainfall = 0.39 + 0.50 + 0.39 + 0.25 + 0.25 + 0.22 + 0.26 (sum of the elements in row 1).
Total number of criteria in row 1 = 7
Therefore, A {weight of factor 1 (F1)} = 2.26/7 = 0.3228 = 0.32.
A% (criteria in percentage) = A x 100 = 0.32 * 100 = 32%, see table 4.6 for more details.

Table 6: Prioritization weight matrix for water irrigation suitability

Criterion	Rainfall	Basin	Flow Acc.	Elevation	Slope	Geology	Soil	Mean	W%	row total of normalized matrix
Rainfall	0.39	0.50	0.39	0.25	0.25	0.22	0.26	0.32	32.20	2.25
Basin	0.19	0.25	0.39	0.31	0.30	0.26	0.20	0.27	27.27	1.91
Flow Accumulation	0.13	0.08	0.13	0.31	0.30	0.26	0.20	0.20	20.18	1.41
Elevation	0.10	0.05	0.02	0.06	0.10	0.13	0.11	0.08	8.20	0.57
Slope	0.08	0.04	0.02	0.03	0.05	0.09	0.09	0.06	5.59	0.39
Geology	0.08	0.04	0.02	0.02	0.03	0.04	0.11	0.05	4.88	0.34
Soil	0.04	0.04	0.02	0.02	0.02	0.01	0.03	0.02	2.39	0.17
Total	1.00	1.00	1.00	1.00	1.05	1.00	1.00	1.01	100.72	7.05

3.3.5. Estimation of the Consistency Ratio

This stage involved calculating a consistency ratio (CR) to check reliability of the judgments values which are relative to large samples of purely random judgments. The AHP deals with consistency explicitly because in making paired comparisons, just as in thinking, people do not have the intrinsic logical ability to always be consistent.
To determine consistency ratio, the analytical hierarchy process compares it by random index (R.I.).
CR = CI/RI
In calculating the constituency value, the mathematical formula CR = CI/RI was be used.
Random index (RI) is the consistency index of a randomly generated pair-wise comparison matrix of order 1 to 10 obtained by approximating random indices.

Table 7: Random Index by Saaty

Size of matrix (n)	1	2	3	4	5	6	7	8	9	10
Random index (RI)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

Source: (Saaty, 2001)

Note: If the value of the obtained Consistency Ratio is less than 0.1, it means that there is a reasonable level of consistency in the pairwise comparisons, and that the computed weights are within the acceptable limit. If the reverse is the case (CR > 0.1) it means that the weights obtained are inconsistent and needs to be checked.

1. The value of Consistency index, CI for water irrigation

suitability was calculated from the preference matrix according to equation below

$$CI = \frac{\lambda max - n}{n-1} \quad (1)$$

λmax is the Principal Eigen Value; n is the number of factors
$\lambda max = \Sigma$ of the products between each element of the priority vector and relative weights
λmax = (2.59*0.32) + (3.99*0.27) + (7.62*0.20) + (16.08*0.08) + (20.83*0.06) + (23.25*0.05) + (35*0.02)
= 0.82 + 1.07 + 1.52 + 1.28 + 1.24 + 1.16 + 0.7
λmax = 7.79
CI = (7.79 – 7)/ (7-1) = 0.131
CR = 0.131/1.32 = 0.09
CR = 0.09 < 0.10 (Acceptable)

3.4. Suitability Calculation

The weighted linear combination (*WLC*) model has become popular in recent year and for the study, WLC methods was used over the Boolean method. Site suitability was calculated by using raster calculator in ArcGIS Pro 2.5. The criteria were standardized to a continuous scale of suitability from the least to the most suitable, thus giving flexibility in the site selection.

The suitability index method permits the assignment of weights, this was implemented in ArcGIS Pro 2.5. In order to make the map easily understandable, a reclassification was performed to define the three suitability index levels/categories—low, moderate and high. The natural breaks reclassification method in ESRI's ArcGIS Pro 2.5 was used for this purpose. The natural breaks (jenks) classification algorithm finds data break points between classes depending on the natural patterns in which the data are clustered. Class break points are set where there are relatively huge jumps in the data values. Hence using the formula to calculate for the following renewable energy Suitability: For water irrigation suitability, WI is = **(**W1*32) + (W2*27) + (W3*20) + (W4*8) + (W5*6) + (W6*5) + (W7*2)). See figure 1.

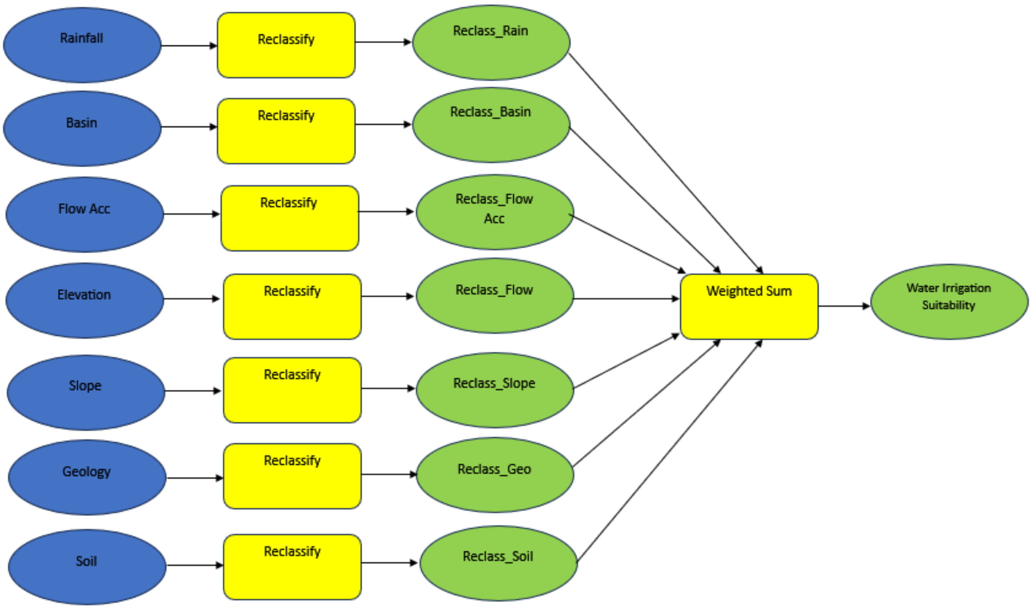

Fig 1: Water Irrigation Suitability Graphic Model

Note: W1... W7 are thematic layers representing the factors for water irrigation suitability, see table 4.8. The output presented potential sites with the highest suitability. The results are shown in Table 8 and 9.

Table 8: Coding of Factors

Code	Factors
B1	Rainfall
B2	Basin
B3	Flow Accumulation
B4	Elevation
B5	Slope
B6	Geology
B7	Soil

Table 9: Water Irrigation Suitability Distribution

Category	Area	Percentage
High Suitability	87.94	10.83
Moderate Suitability	310.70	38.29
Low Suitability	412.69	50.88
Total	811.33	100

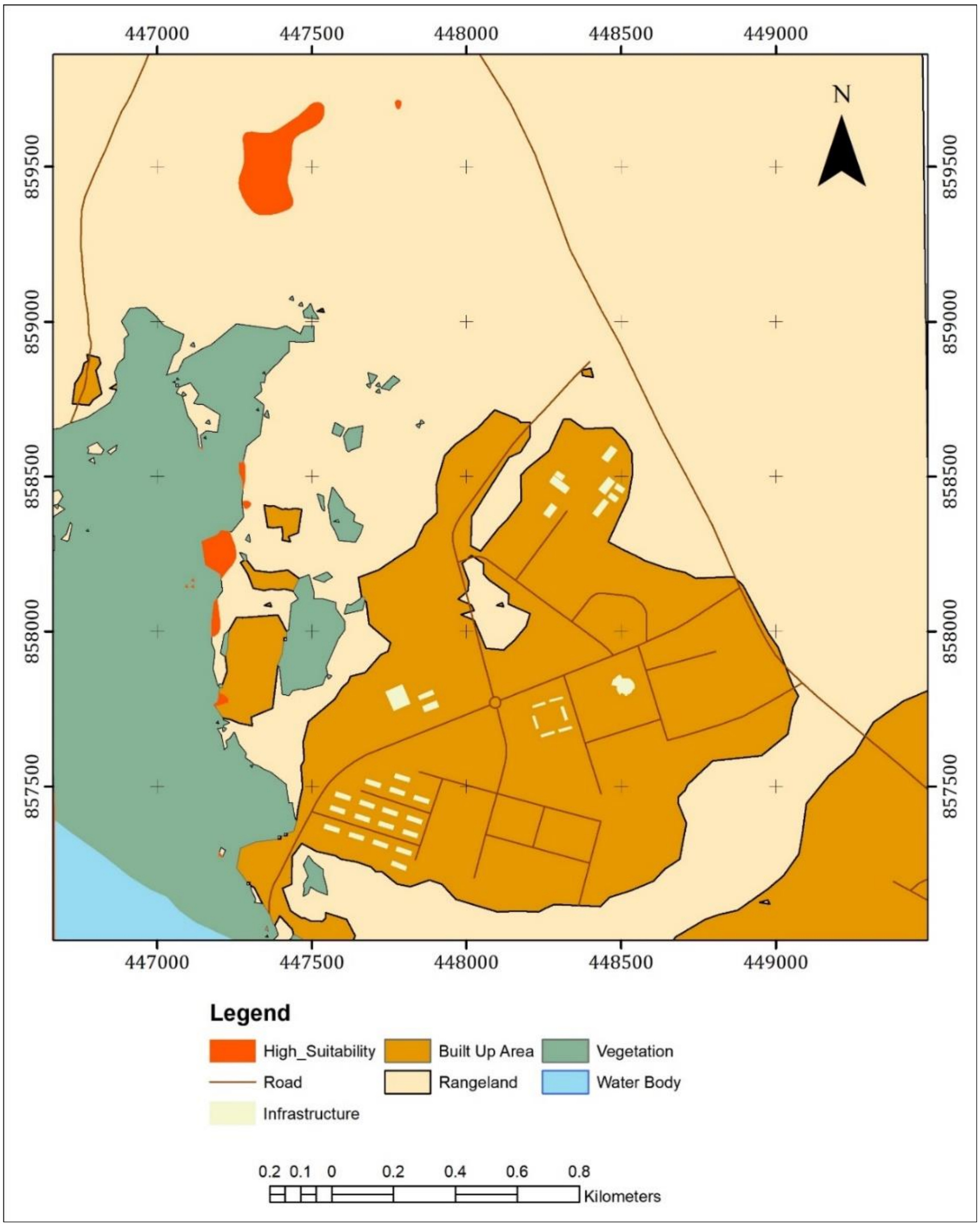

Fig 2: Map showing suitable locations for Water Irrigation Suitability

The analysis identified three distinct suitability zones within the study area for water irrigation purposes. These zones are categorized as high, moderate, and low suitability based on their potential for effective irrigation. The high suitability zone covers 87.94 hectares, representing 10.83% of the study area. The moderate suitability zone spans 310.70 hectares, accounting for 38.29%, while the low suitability zone extends over 412.69 hectares, making up 50.88% of the area.

The identification of these suitability zones is crucial for optimizing irrigation strategies within the study area. By understanding the specific areas that are most suitable for irrigation, resource allocation can be more effectively managed, ensuring that water resources are utilized in the most efficient and sustainable manner.

This finding has significant implications for agricultural planning, allowing farmers and planners to focus their efforts and resources on high and moderate suitability zones to maximize crop yield and productivity. Low suitability areas might require additional interventions, such as soil amendments or alternative irrigation methods, to enhance their productivity. In terms of resource management, the results provide a basis for targeted investment in irrigation infrastructure, ensuring that high-return areas are prioritized, thereby optimizing the use of financial and natural resources. Additionally, water conservation measures can be more effectively implemented, reducing waste and promoting sustainable agricultural practices.

The study adds value to scientific knowledge by contributing to the growing body of research on precision agriculture and sustainable resource management. By integrating geographic information systems (GIS) and remote sensing techniques to delineate irrigation suitability zones, the study demonstrates the practical application of these technologies in agricultural planning and management. The methodology and findings can serve as a model for similar studies in other regions, promoting the adoption of advanced analytical techniques in environmental science and agriculture.

For the Nigerian Army College of Environmental Science and Technology, this study serves as a valuable educational resource for students and researchers, providing a practical example of how GIS and remote sensing can be applied in real-world scenarios. It enhances the curriculum and fosters a deeper understanding of these technologies. The findings can inform strategic planning and decision-making within the College, particularly in its efforts to support sustainable agricultural practices and resource management in Nigeria. Additionally, the study opens avenues for further research and development within the College, allowing for future studies to build on this work and exploring additional factors that influence irrigation suitability. Collaborative projects with other academic and research institutions can be initiated, positioning the College as a leader in environmental science and technology research in Nigeria.

Overall, the study provides immediate practical benefits for agricultural management in the study area while also enhancing the scientific and educational capabilities of the Nigerian Army College of Environmental Science and Technology.

4. Conclusion

The study successfully identified three distinct water irrigation suitability zones within the study area: high, moderate, and low. The high suitability zone covers 87.94 hectares, accounting for 10.83% of the total area. The moderate suitability zone spans 310.70 hectares, representing 38.29%, while the low suitability zone extends over 412.69 hectares, making up 50.88% of the area. These findings provide a framework for optimizing irrigation strategies, allowing farmers and agricultural planners to enhance crop yield and productivity by focusing on high and moderate suitability areas, thereby making efficient use of available water resources.

The results highlight the need for targeted investment in irrigation infrastructure in high-return areas, while also identifying low suitability zones that may require additional interventions such as soil amendments or alternative irrigation methods. This underscores the importance of effective resource management, promoting water conservation and sustainable agricultural practices. The study supports the implementation of strategic water use measures, reducing waste and ensuring long-term sustainability.

5. Reference

1. Adeniyi PO. Land Use and Land Cover Change in Nigeria: An Inventory from Landsat MSS Imagery. Nigerian Geographical Journal. 1993;27(1&2):29-39.
2. Adeoye NO, Ibitoye MO, Ibitoye OA. Hydrological Characteristics and Sustainable Yield in Iju and Owena Reservoirs. Nigerian Journal of Geography and the Environment. 2009;1:35-47.
3. Aderamo AJ. Water Supply in Ilorin, Nigeria. GeoJournal. 2002;56(2):165-173.
4. Ajayi AA, Ogunniyi LT. Determinants of Climate Change Adaptation Strategies on Crop Production in Southwestern Nigeria. Journal of Agricultural and Biological Science. 2013;8(4):333-339.
5. Ajayi JO. Land Use and Land Cover Changes in Developing Countries: A Case Study of Nigeria. Journal of Soil and Water Conservation. 1987;42(3):206-210.
6. Akanmu O. Groundwater Quality in the Niger Delta. International Journal of Water Resources Development. 2011;27(2):385-391.
7. Akintola JO. Rainfall Distribution in Nigeria 1892-1983. Impact Publishers Nig. Ltd; c1986.
8. Allan JA, Keulertz M, Woertz E. The Water-Food-Energy Nexus: An Introduction to Nexus Concepts and Some Conceptual and Operational Problems. International Journal of Water Resources Development. 2005;21(1):1-17.
9. Ayoade JO. Water Resources and Their Development in Nigeria. Hydrological Sciences Journal. 1975;20(4):581-591.
10. Ayoade JO. Tropical Hydrology and Water Resources. Macmillan Publishers Ltd; c1988.
11. Balogun O. Senior Secondary Geography. Longman Nigeria Plc; c2003.
12. Chukwuma EC. Management of Water Resources in Nigeria: Issues and Problems. Nigerian Journal of Hydrology and Hydrogeology. 1993;3:21-30.
13. Dai A. Drought Under Global Warming: A Review. WIREs Climate Change. 2016;2(1):45-65.
14. Ezeabasili ACC. Water Resources Management Problems in Nigeria: Challenges and Future Directions. Water International. 2009;34(4):421-429.
15. Ezenwaji EE, Ejikeme J. An Appraisal of Water Supply Situation in Awka Town, Anambra State, Nigeria. Journal of Environmental Management and Safety. 2014;5(1):45-57.
16. FAO. The Future of Food and Agriculture – Trends and Challenges. Food and Agriculture Organization of the United Nations; c2017.
17. FAO. The State of World Fisheries and Aquaculture 2018. Food and Agriculture Organization of the United Nations; c2018.
18. Gleick PH. Water, Drought, Climate Change, and Conflict in Syria. Weather, Climate, and Society. 2014;6(3):331-340.
19. Goni IB, Ali HA. Water Scarcity in Kano and Its Implications for Sustainable Development. Journal of Sustainable Development Studies. 2015;8(1):65-84.
20. IEA. World Energy Outlook 2015. International Energy Agency; c2015.
21. IPCC. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; c2014.
22. Keller AA, Keller J, Davids G. River Basin Development Phases and Implications of Closure. Journal of Applied Irrigation Science. 2000;35(2):147-163.
23. NBS. Nigerian Gross Domestic Product Report Q2 2020. National Bureau of Statistics; c2020.
24. Nwafor JC. Global Climate Change: The Driver of Multiple Causes of Flood Intensity in Sub-Saharan Africa. African Journal of Environmental Studies. 2007;5(1&2):1-9.
25. Nwankwoala HO. Coastal Aquifers of Nigeria: An Overview of Its Management and Sustainability Considerations. Coastal Research Library. 2015;12:151-170.
26. Nzewi UM. Water Supply and Demand in Owerri Town, Imo State. Journal of Mining and Geology. 1989;25(1&2):273-281.
27. Offodile ME. Groundwater Study and Development in Nigeria. Mecon Geology and Engineering Services Ltd; c2002.
28. Ofomata GEK. Nigeria in Maps: Eastern States. Ethiope Publishing House; c1975.
29. Ojo O. The Climate of West Africa. Heinemann Educational Books; c1977.

30. Ojo O. Fundamentals of Physical and Dynamic Climatology. SEDEC Publishers Ltd; c2012.
31. Okechukwu EM, Chukwu DI. Effect of Rainfall on Water Supply in Owerri, Imo State, Nigeria. International Journal of Scientific and Engineering Research. 2017;8(8):1918-1925.
32. Oladipo EO. Some Aspects of the Spatial Characteristics of Drought in Northern Nigeria. Natural Hazards. 1993;8:171-188.
33. Olomola AS. Understanding the Framework for Intergovernmental Interventions in Rice Production in Nigeria: Perspectives from the Federal, State, and Local Governments. Nigerian Institute of Social and Economic Research (NISER); c2015.
34. Olorunfemi FB. Geographical Perspectives on Drought in Nigeria. Nigerian Geographical Journal. 1983;26(1&2):97-104.
35. Olorunfemi FB, Raheem UA. Urban Vulnerability to Climate Change and Natural Hazards in Nigeria. In Climate Change and Natural Disasters in Nigeria: Physico-socio-economic Impacts. Nigerian Association of Hydrological Sciences; 2007:150-169.
36. Oni KA. Agricultural Productivity and Economic Growth in Nigeria. Journal of Economics and Sustainable Development. 2018;9(14):11-22.
37. Onugba I. Water Scarcity in Benue State and Its Impact on the Socio-Economic Development of Rural Communities. Journal of Water Resources and Environmental Management. 2018;4(1):123-137.
38. Orebiyi JS, Awoniyi SMO. The Roles of Irrigation in Sustainable Food Production and Agricultural Development in Nigeria. Journal of Agricultural Economics and Rural Development. 2010;3(2):65-74.
39. Osinubi TS. Urban Poverty in Nigeria: A Case Study of Agege Area of Lagos State, Nigeria. Journal of Economic and Social Studies. 2003;45(4):201-229.
40. Oyebande L. The Effect of Urbanization on the Water Resources of Lagos Area, Nigeria. Nigerian Geographical Journal. 1973;16(1):61-78.
41. Pinter N, Jemberie AA, Remo JWF, Heine RA, Ickes BS. Flood Trends and River Engineering on the Mississippi River System. Geophysical Research Letters. 2016;33(16).
42. Postel S. Pillar of Sand: Can the Irrigation Miracle Last? W.W. Norton & Company; c1999.
43. Shiklomanov IA. Appraisal and Assessment of World Water Resources. Water International. 2000;25(1):11-32.
44. Ufoegbune GC, Awomeso JA, Idowu OA. Impact of Climate Change on Water Resources at Oyan Dam in Ogun State, Nigeria. Journal of Water Resource and Protection. 2011;3:521-526.
45. UNEP. The UN-Water Status Report on the Application of Integrated Approaches to Water Resources Management. United Nations Environment Programme; 2012.
46. Vörösmarty CJ, Green P, Salisbury J, Lammers RB. Global Water Resources: Vulnerability from Climate Change and Population Growth. Science. 2000;289(5477):284-288.
47. WHO. Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum. World Health Organization; c2018.
48. World Bank. High and Dry: Climate Change, Water, and the Economy. World Bank; c2016.