# Identification of Potential Sites for Rainwater Harvesting Structures in Akwa Ibom State, Nigeria: RS and GIS Approach

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***Abstract:***
Water is the most essential resource on earth for life's existence. Changing hydrological phenomena and increase of water demand generally, create serious water scarcity problems. Precipitation and underground water are major sources to mitigate this problem. Construction of water harvesting structures across watersheds is gaining drive recently to improve efficiency and effectiveness in water availability, supply, use, and water demand for various purposes. In this study, geographical information system (GIS) and remote sensing (RS) techniques integrated with multi-criteria analysis were used to achieve study objectives – identify possible locations for water harvesting structures using GIS and structure type. Considering the complexity of identification of the water harvesting structures sites, Analytical Hierarchy Process (AHP) was used to determine the weight of importance of five criteria used for the suitability analysis: rainfall, slope, drainage density, land cover and soil texture. These factors were ranked based on their importance to water harvesting structure and the weight generated from the AHP, the criteria were combined using the weighted overlay techniques (WOT). Dam and pond locations were identified from the suitability map generated. 1.06% and 1.88% of the study area fall within areas of high suitability for pond and dam constructions respectively. The highly suitable area falls within the area of very high rainfall intensity and a gentle slope.

***Keywords:*** Potential, Rainwater, Structures, Remote Sensing, Geographical Information System, Nigeria.

## 1. Introduction

Water, one of the most essential natural resources for the survival of life is seriously depleting in both urban and rural areas, majorly due to the alarming rate of population increase, with an attendant increase in agricultural and domestic demands, [1]. Different water conservation practices, over time, is applied to reduce surface runoff and divert it to recharge zones in order to increase moisture and crop production [2]. Reliable runoff conservation can allocate water efficiently for competing water users like agriculture, hydropower generation, and domestic purposes for maintenance of environmental flows [3].

The structures that are built for watershed management imply an overall improvement in the water scenario and hence an increase in biomass so as to fulfil the people's basic needs in an existing watershed. The approach mainly focuses on reducing runoff, soil loss, and augmentation of infiltration. Constructing suitable structures is one of the practices for a reduction in surface runoff by changes in land management, which in turn will increase infiltration and aid water conservation [4].

It is estimated by the United Nations Environment Program that above 2 billion people will live under conditions of nonstandard water hassle by 2050 [5]. There has been increasing universal water utilization in domestic, industrial, and agricultural areas [6]. The United Nations via its millennium development goals (MDGs) and sustainable development goals (SDGs) stressed for universal and provincial collaboration to ascertain water concerns and then resolve them cooperatively [7].

Very nearly 85% of the Earth's freshwater falls specifically into the ocean and never reaches the land. The little leftover portion that hastens on the land tops off the rivers, lakes and wells, and furthermore keeps the waterway streaming. For each 50,000 grams of seawater, just a single gram of crisp water is accessible to humanity making it a rare and valuable product. Water covers around 75% of the world's surface [8]. The aggregate volume of water has been evaluated to be in excess of 1400 million Km3, enough to cover the whole earth with a layer of 300m in thickness. About 97.0% of this water makes up the seas. The balance of 3.0% constitutes 79% portion that solidified in the Polar Regions. In this manner, all the rest of the water in the lakes and streams, in underground repositories and in type of dampness in the air, soil and vegetation, adds up to just about 0.6% of the aggregate. Of this 0.6% (that is fluid new water), just 53% is accessible as stream and lake water. Shockingly it is the salt water of the seas that is a definitive wellspring of crisp water on this planet [9].

To achieve optimum use of water harvesting structures in relation with cost of construction, the site must be one with a good stream flow, great head (that is to say the storage capacity expected from the dam should be very high), good topography and good soil formation (igneous or metamorphic soil formation), etc. When it comes to having a good soil formation for dam construction, Akwa Ibom state does not have a suitable site as most of its soil is sedimentary in nature. This poses a great problem as a dam with great storage capacity is not viable and so the state will still lose a substantial volume of runoffs to the seas and oceans.

With all these posing a great threat to the existence of the increasing population of humans, plants and animals utilizing this scarce resource. It is necessary for every major catchment in Akwa Ibom State, Southern Nigeria, to have a good water harvesting structure constructed across these catchments to enhance quality water storage for man’s usage, and for the purpose of this study, agricultural activities all year round.

In this study, the suitable sites for constructing Water Harvesting Structures (WHS) in the watershed areas of Akwa Ibom State were identified using the remote sensing and geographic information system (GIS) techniques. There is dearth or no information from literatures regarding the identification of sites suitable for WHS in the study. Identification of most probable sites for water harvesting structures needs a large volume of multidisciplinary inputs from different sources for which the applications of modern remote sensing and geographic information system (GIS) techniques have gained much interest in recent years [10].

## 2. Materials and Methods

### 2.1 Study Area

Akwa Ibom State is located on the coastal and southern part of Nigeria and covers a total area of 8,412km2, encompassing the Qua Iboe River Basin, the western part of the lower Cross River Basin and the Eastern part of the Anambra/Imo River Basin. Akwa Ibom State lies between latitude 4° 32’ and 5° 53’ North of the Equator; and Longitudes 7° 25’ and 8° 25’ East of the Greenwich Meridian [11], as shown in Figure 1 below. It has a total population of about 5 million people and it is the highest oil and gas producing state in the country. The state is bothered in the south by the Atlantic Ocean.

The topography of the study area being mostly flat areas around Itu and Ibiono Ibom Local Area Councils, undulating with some areas as high as 200 feet above sea level, while there are valleys, marshes, ravines and swamps due to influence of the Atlantic Ocean, Qua Iboe, Imo and the Cross Rivers in other areas [12]. This is as a result of the underlying geology of the state which is predominantly coastal plain sediments. The coastal nature of the state makes it the natural deposit of mosaic of marine, deltaic, estuarine, lagoonal and fluvio- lacustrine material.

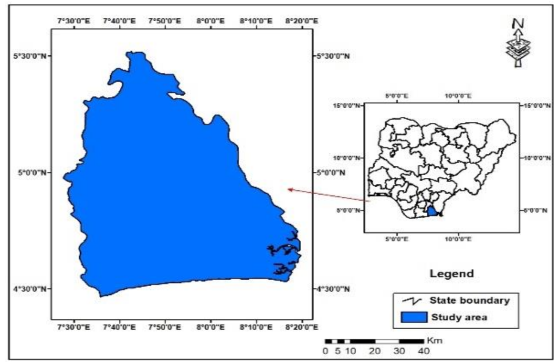


Figure 1: Map of the Study Area

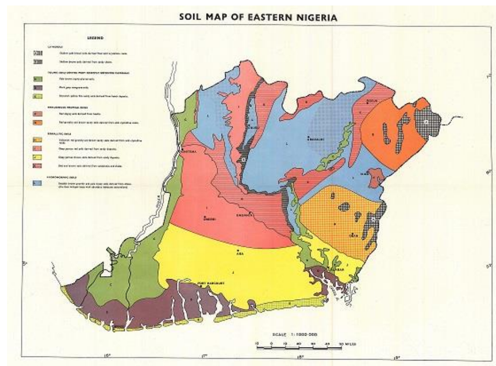


Figure 2: Soil Map of South Eastern Nigeria [12]

The study area is characterized by two major climatic seasons; the wet season and the dry season. The wet season lasts between the month of March and October and in some years may extend to November. The dry season is usually experienced between the months of December to February. The geographic location of Akwa Ibom S could be described as a tropical rain forest region. The rainfall is usually heavy ranging from 3000mm along the coast and 2000mm on the northern fringe. The highest temperature throughout the year is between 27°C to 29°C while the relative humidity is high with a value of 60 - 90% [11]. The area is characterized by loose, friable and unconsolidated ferrallitic soils of the coastal plains sand which are deficient in weatherable mineral reserves. The soils of the area cover deep down the ground and are composed of loamy sand and sandy surface materials. Soil types include coarse sand, fine sand, very fine sand, silt and clay. The geological succession in Akwa Ibom State reflects the progressive growth of the delta into the Gulf of Guinea and consists of mostly shales, sandstones, sands and clays representing the transgression and regression which characterized the development of the southern sedimentary Basin. The deltaic and continental Bende-Ameke group represents the regressive phase which is still continuing. Generally, the study area belongs to the low-lying coastal/deltaic plains of Southern Nigeria [13].

### 2.2 Data source

Primary data sources include an annual rainfall data of the study area from Nigeria Meteorological Agency (NIMET). The soil data used for this study were obtained from the outlook in parts of the study area and based on the field survey done by the Soil

Survey Division of the Federal Department of Agricultural Land Resources (FDALR) Nigeria, Figure 2.

Optical multispectral imagery from Landsat was used for this study. The LANDSAT data were downloaded from USGS Earth Explorer the Operational Land Imager (OLI) for 27th Dec., 2018. The data was used for the image classification of the study area. Shuttle Radar Topography Mission (SRTM) imagery with a 30m resolution was downloaded for study area from the United States Geological Survey [14] Website. The SRTM data would serve as the DEM data for the study as shown in Figures 3 and 4.

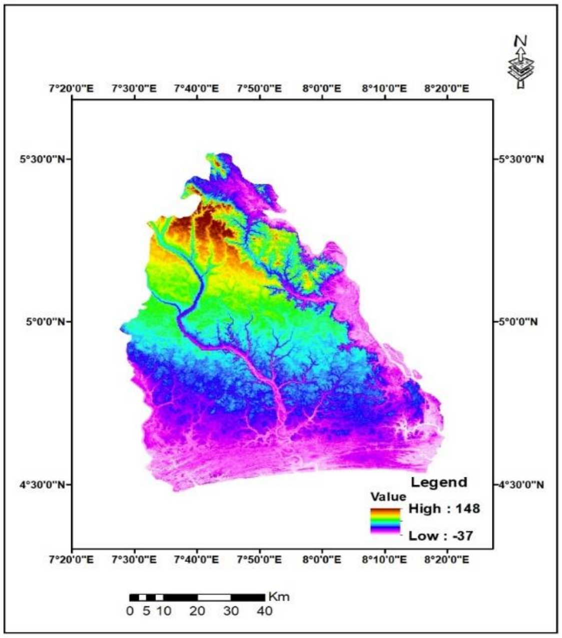


Figure 3: DEM of the Study Area

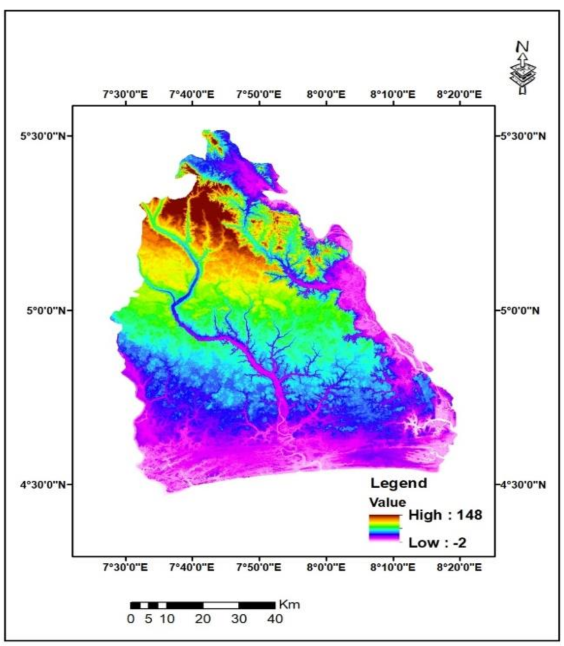


Figure 4: Fill DEM of the Study Area

*2.3 Method*

This study employed Remote Sensing (RS) and Geographic Information System (GIS) to identify suitable sites for rainwater harvesting site. The method adopted is illustrated in the flowchart below, Figure 5. The identification of the suitable site for rain water harvesting was executed in four stems (a). Criteria selection (b). Criteria suitability ranking (c). Suitability evaluation (d). Suitability site identification.

In 2003, the Food and Agriculture Organization of the United Nations (FAO), listed six main criteria for identifying Rain Water Harvesting sites: climate, hydrology, topography, agronomy, soils, and socio-economics [15]. This study used five criteria to identify locations suitable for rainwater harvesting structures such as small dams or pond. These criteria were selected based on review of several literatures, availability of data and expert judgement. In line with the FAO recommendation, Rainfall data was used to compute the parameter for climate; stream order and drainage density data as a parameter for hydrology; slope data as a parameter for topography; land-use/landcover as a parameter for agronomy and soil texture as the parameter for soil.

Due to the variation of measurements and scales for the different criteria, a comparable scale between criteria must be identified before applying it for the next stage. For instance, rainfall intensity is measured in mm while soil texture is measured by the percentage of clay content. The criteria used were all reclassified based on their suitability to Rain Water Harvesting (RWH) structures. The reclassified raster was given new pixel value for 1 to 5. The suitability ranking for each criterion used for this work is illustrated in Table 1. The most suitable criteria class was reclassified as 5 and the least suitable were classified as 1. The suitability ranking is based on expert knowledge and information gotten from previous works [15-19].

To achieve generating the weight value for each criterion, the Multi-Criteria Analysis (MCA) was integrated with GIS. The application of MCA in a GIS environment employed in this study was implemented in two stages. The application of MCA in a GIS environment, and the application of a GIS followed by the definition of weights and scores for the criteria by Analytical Hierarchy Process (AHP). MCA is a very common method in GIS-based decision making that is based on different criteria. However, the decision can be based on factors or constraints. The purpose of this process is to find the most suitable locations for RWH structures within the study-area. This process was done by MCA which allows the combination of several relevant criteria to determine suitable outcome [20]. Generating the suitability map is done by integrating different criteria map using the weighted overlay operation in GIS environment. The criteria used for the identification of suitable site for RWH structures are not of equal importance. Therefore, different weights were assigned to the criteria base on their importance. AHP is one of the specific methods of site suitability of structures, which is based on multi-Criteria decision-making technique that was originally developed by [21].

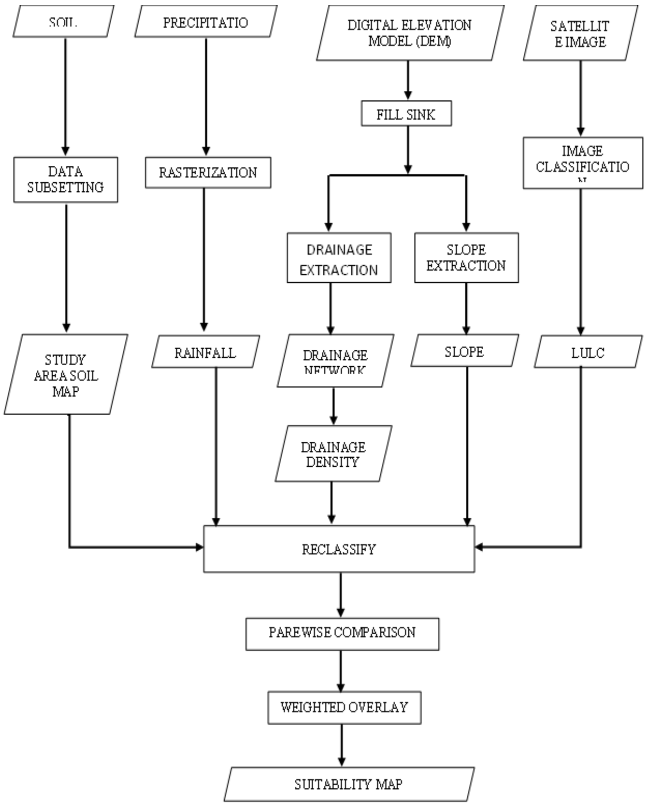


Figure 5: Flowchart of methodology

Table 1: Classification, suitability scores for each criterion for assessment of suitability site for RWH structures in the study. Each value, class and score were rated based on the literature review, information from the discussions with experts.

| CRITERIA | CLASS | VALUE (DAM) | SCORE (DAM) | VALUE (POND) | SCORE (POND) |
|---|---|---|---|---|---|
| SLOPE | | 0 – 2 | 5 | 0 - 1 | 5 |
| | | 2 - 5 | 4 | 1 - 2 | 4 |
| | | 5 - 8 | 3 | 2 - 3 | 3 |
| | | 8 - 10 | 2 | 3 - 5 | 2 |
| | | >10 | 1 | >5 | 1 |
| LANDUSE | Built up | | Restricted | | Restricted |
| LANDCOVER | Bareland | | 4 | | 4 |
| | Shrub land | | 5 | | 5 |
| | Forested | | 1 | | 1 |
| | Farmland | | 2 | | 2 |
| | waterbody | | Restricted | | Restricted |
| RAINFALL | | 2456 - 2717 | 1 | 2456 - 2717 | 1 |
| | | 2718 - 2856 | 2 | 2718 - 2856 | 2 |
| | | 2857 - 2969 | 3 | 2857 - 2969 | 3 |
| | | 2970 - 3079 | 4 | 2970 - 3079 | 4 |
| | | 3080 - 3259 | 5 | 3080 - 3259 | 5 |
| DRAINAGE | | >0.62 | 5 | >0.62 | 5 |
| | | 0.47 – 0.62 | 4 | 0.47 – 0.62 | 4 |
| | | 0.31 – 0.47 | 3 | 0.31 – 0.47 | 3 |
| | | 0.15 – 0.31 | 2 | 0.15 – 0.31 | 2 |
| | | 0 – 0.15 | 1 | 0 – 0.15 | 1 |
| SOIL | Sand clay loam | | 3 | | 3 |
| TEXTURE | Sand clay | | 4 | | 4 |
| | Silt clay | | 5 | | 5 |
| | Sandy loam | | 2 | | 2 |
| | Sandy | | 1 | | 1 |
| | Loam | | 2 | | 2 |

Source: [15-19]

The Analytical Hierarchy Process (AHP) was used to determine the weight of each criterion base on pairwise comparisons of the criteria. Criterion with higher weight is more important than the others.

Pairwise comparison indicates the relative importance of two criteria involved in determining the suitability for a given objective. A pairwise matrix is first made for the main decision criteria being used. Other pairwise matrixes are created for additional criteria levels. The comparison and rating between two criteria were conducted using a 9-point continuous scale, the odd values 1, 3, 5, 7 and 9 correspond respectively to equally, moderately, strongly, very strongly and extremely important criteria when compared to each other. The even values 2, 4, 6 and 8 are intermediate values [22]. The pairwise comparison, criteria were rated based on the literature review and expert opinion. The final weight calculation requires the computation of the principal eigenvector of the pairwise comparison matrix using the row geometric mean method (RGMM) by [23] to produce a best-fit set of weights using the formula below:

$$r_i = \exp\left[\frac{1}{N}\sum_{j=1}^{N} \ln\left(a_{ij}\right)\right] = \left(\prod_{i=1}^{N} a_{ij}\right)^{1/N} \quad (1)$$

$$p_i = r_i \cdot / \sum_{i=1}^{N} r_i$$

N = number of criteria

Priorities $p_i$ in each input sheet are calculated using the row geometric mean method (RGMM). With the pairwise NxN comparison matrix $\mathbf{A} = a_{ij}$

The consistency of each matrix, which shows the degree of consistency that has been achieved by comparing the criteria, was checked through the calculation of consistency ratio (CR). The final weight for each criterion and the CR, was determine mathematically from the pairwise matrixes. The consistency ratio was calculated using equation 2 and 3.

CR = $CI/RCI$ 2

where: RCI is random consistency index and

CI is consistency index, which is given as:

$CI = (\boldsymbol{\lambda}\text{max} - n)/(n-1)$ 3

where: $\boldsymbol{\lambda}max$ is principal eigen-value computed by eigen-vector technique and

n is the number of criteria (factors).

[24] recommended that the value of CR should be less than 0.1; otherwise, the weights should be re-evaluated to maintain consistency.

To generate the suitability map showing the suitable site for RWH structures. This was calculated using the weight overlay tool in ArcGIS 10.5. The weight overlay process implemented involves the combination of reclassified data from several criteria with cell values of a common scale and assigning weights, and aggregating the weighted cell values [25]. The result of this computation is the suitability map.

## 3. Result and Discussion

Slope were generated using an elevation dataset (DEM) in which the maximum rate of change in elevation over distance between each cell and its eight neighbours is calculated. The result shows a representation of: the lower the slope, the flatter the terrain and the higher the slope, the steeper the terrain. The slope of land is important in suitable site selection for RWH structures.

Table 2: Suitability Ranking Score for Slope

| CRITERIA | CLASS | VALUE (DAM) | SCORE (DAM) | VALUE (POND) | SCORE (POND) |
|---|---|---|---|---|---|
| SLOPE | | 0 - 2 | 5 | 0 - 1 | 5 |
| | | 2 - 5 | 4 | 1 - 2 | 4 |
| | | 5 - 8 | 3 | 2 - 3 | 3 |
| | | 8 - 10 | 2 | 3 - 5 | 2 |
| | | >10 | 1 | >5 | 1 |

Ponds are generally more appropriate in areas having a rather flatter slope though a slight slope is needed for better harvesting of the runoff and siting of pond. The slope in Figures 6 show the location of steep and flat terrains in the study area. The classified slope map in Figures 7 and 8 show the suitability class of the slope map for ponds and dam respectively, while Figure 9 and 10 show that the suitability ranking of the study are in relation to the slope value. It is observed from Figures 9 and 10 that for both Ponds and dams, the Northern part of the study area around Ini Local Government Area have high slope value than the Southern region of the study area. It is also observed that in the southern regions, areas around Okobo, Oron, Udung Uko, Mbo and Ikot Abasi LGA regions have gentle slopes with the highest suitability ranking score and are better placed as suitable sites for rainwater harvesting structures while areas with steep slopes would not be accepted; if slope were to be the only criteria for selecting sites for RHS. The land use/land cover for study area was classed into six classes – Water body, builtup, Bare land, farmland and forest, Tables 3 and 4.

Table 3: Land use/ land cover of the Study area

| S/no | CLASS | AREA COVERAGE (%) |
|---|---|---|
| 1 | Built up | 7.63 |
| 2 | Shrub land | 37.57 |
| 3 | Forest | 38.36 |
| 4 | Bareland | 0.33 |
| 5 | Farmland | 14.93 |
| 6 | Waterbody | 1.18 |

Table 4: Suitability Ranking Score for Landuse/Landcover

| CRITERIA | CLASS | VALUE (DAM) | SCORE (DAM) | VALUE (POND) | SCORE (POND) |
|---|---|---|---|---|---|
| LANDUSE | Built up | | Restricted | | Restricted |
| LANDCOVER | Bareland | | 4 | | 4 |
| | Shrub | | 5 | | 5 |
| | land | | 1 | | 1 |
| | Forested | | 2 | | 2 |
| | Farmland | | Restricted | | Restricted |
| | waterbody | | | | |

It is observed here that forest covers larger portions of the study area as shown in Table 3 and Figure 11 below. The land use/land cover result was reclassified to represent the suitability ranking of each class to siting pond or dams as shown in Figures 12 and 13.

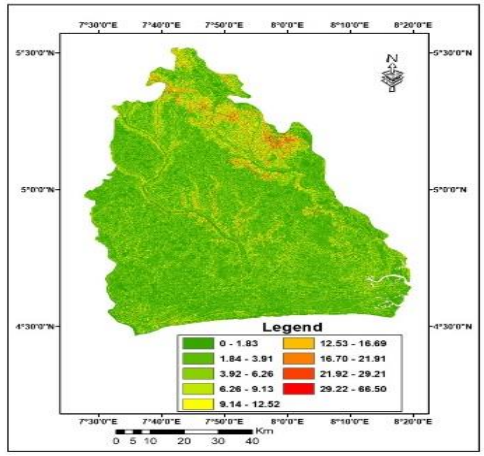


Figure 6: Map Showing the Slope in Percentage Rise of the Study Area

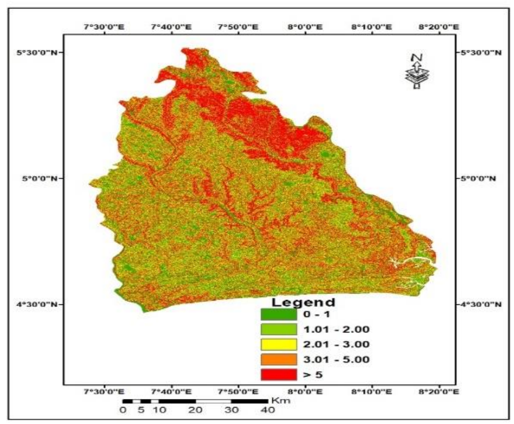


Figure 7: Classified Slope Map for Ponds

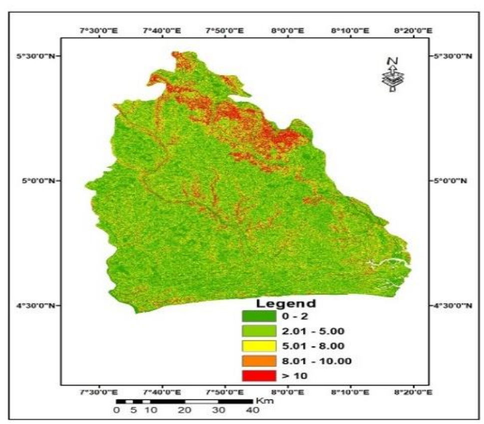


Figure 8: Classified slope Map for Dams

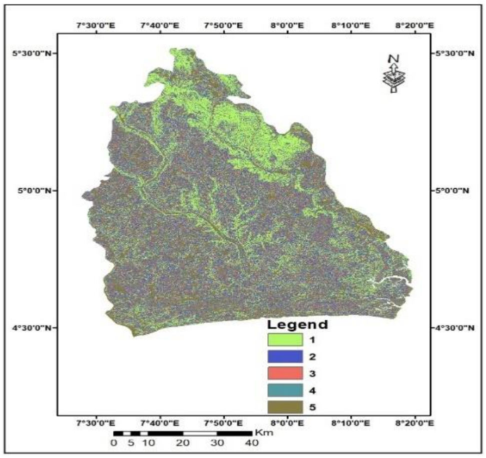


Figure 9: Map Showing slope Suitability Ranking for Pond

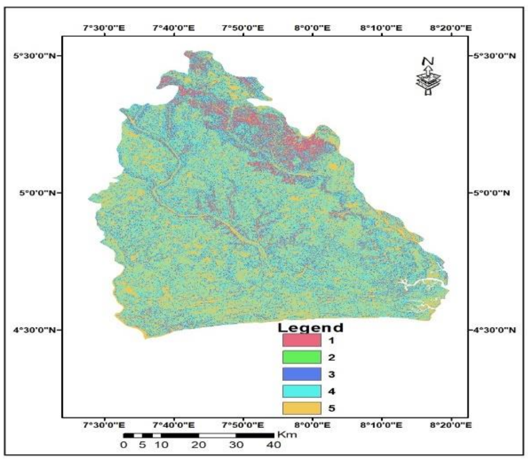


Figure 10: Map Showing slope Suitability Ranking for Dam

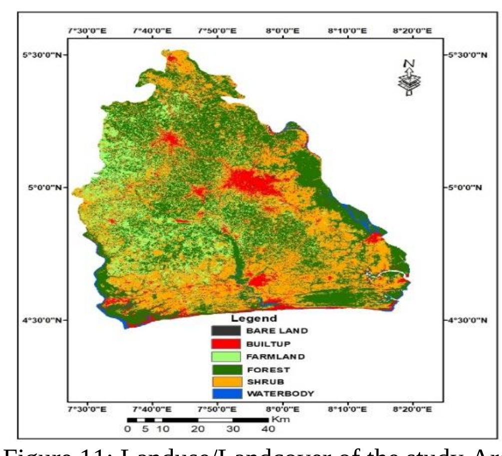


Figure 11: Landuse/Landcover of the study Area

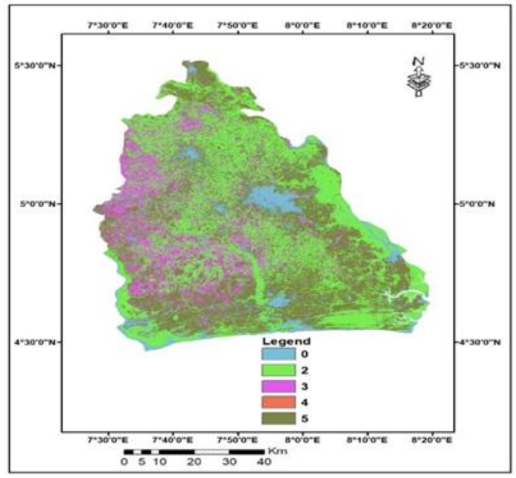


Figure 12: Map Showing Landuse/ Landcover Suitability Ranking for Pond

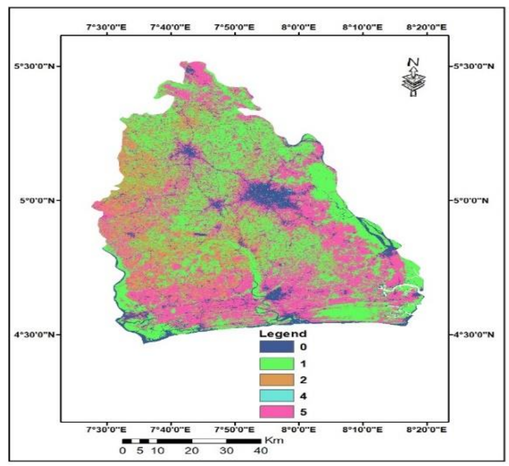


Figure 13: Map Showing Landuse/ Landcover Suitability Ranking for Dam

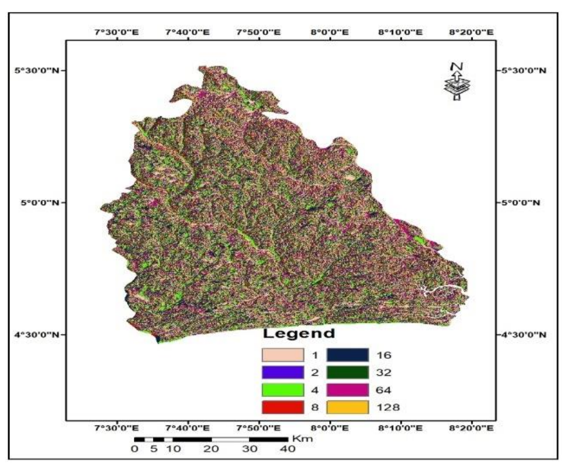


Figure 14: Flow Direction Map of the study area

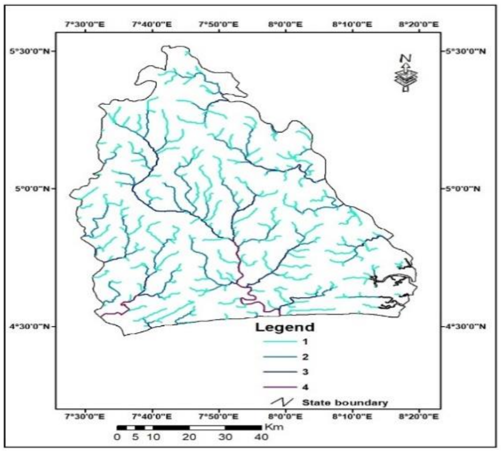


Figure 15: Stream Order Map of The Study Area

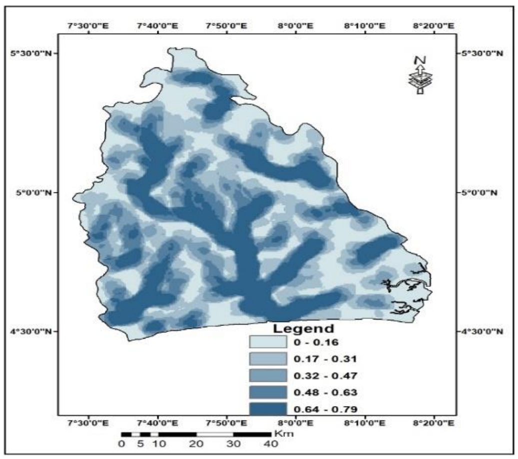


Figure 16: Drainage Map of the Study Area

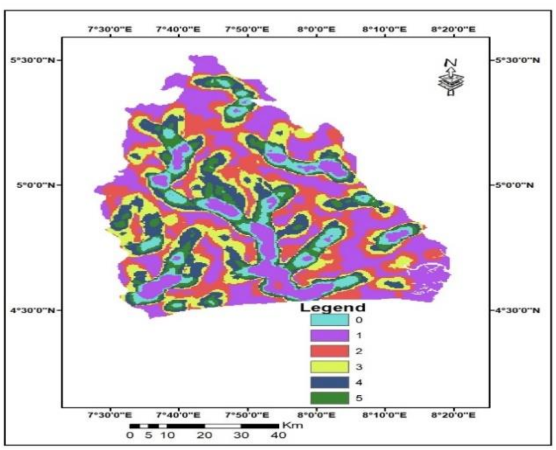


Figure 17: Drainage Suitability Ranking Map for Pond and Dam

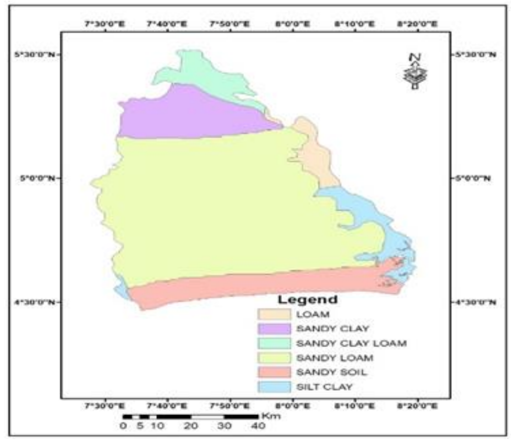


Figure 18: Soil Map of the Study Area

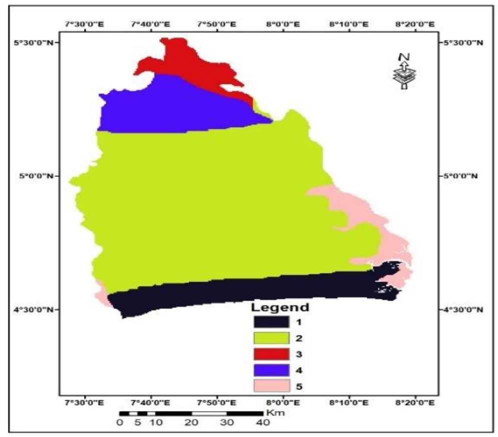


Figure 19: Soil Suitability Ranking Map for Pond and Dam

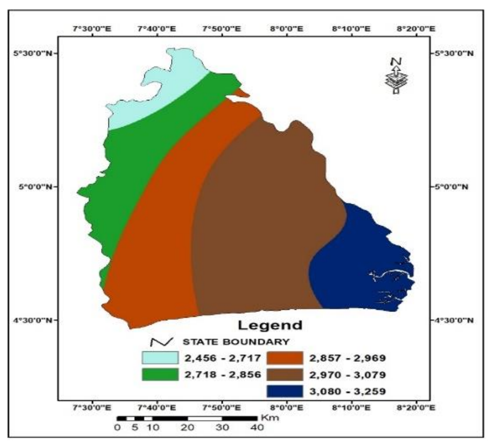


Figure 20: Rainfall Map of the Study Area

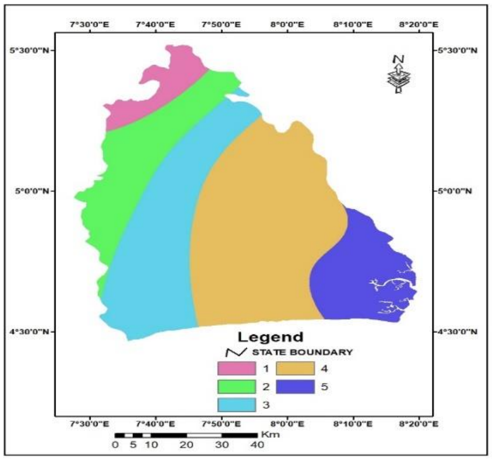


Figure 21: Rainfall Suitability Map for Pond and Dam

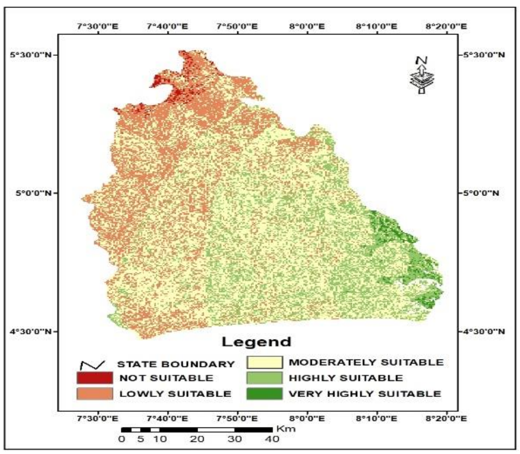


Figure 22: Pond Suitability Map

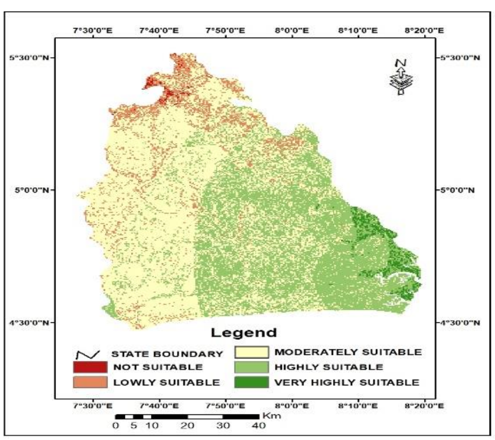


Figure 23: Dam Suitability Map

The drainage density was generated using the stream network. The result from the suitability ranking score in Table 5 was reclassified to generate the suitability ranking map as shown in the Figure 17 below. The result shows areas closest to higher order stream were ranked higher while area far from the threshold distance were ranked as zero. To generate the drainage density map as seen in Figure 16 from the DEM, the flow direction and stream order (Figure 15) was calculated and respectively represented in Figures 14 and 15.

**Table 5:** Suitability Ranking Score for Drainage

| CRITERIA | CLASS | VALUE (DAM) | SCORE (DAM) | VALUE (POND) | SCORE (POND) |
|---|---|---|---|---|---|
| DRAINAGE | | >0.62 | 5 | >0.62 | 5 |
| | | 0.48 – 0.62 | 4 | 0.48 – 0.62 | 4 |
| | | 0.32 – 0.47 | 3 | 0.32 – 0.47 | 3 |
| | | 0.16 – 0.31 | 2 | 0.16 – 0.31 | 2 |
| | | 0 – 0.15 | 1 | 0 – 0.15 | 1 |

The soil texture map was derived from field survey done by the Soil Survey Division of the Federal Department of Agricultural Land Resources (FDALR) Nigeria. The result shows the different type of soil texture in the study area, Table 6. The soil map was rasterized and the reclassified into suitability rank. The silt clay class have the highest suitability rank for the study area. The soil map and the soil suitability map for both pond and dams are shown in Figure 18 and 19, respectively.

**Table 6:** Suitability Ranking Score for Soil Texture

| CRITERIA | CLASS | VALUE (DAM) | SCORE (DAM) | VALUE (POND) | SCORE (POND) |
|---|---|---|---|---|---|
| SOIL TEXTURE | Sand clay loam | | 3 | | 3 |
| | Sand clay | | 4 | | 4 |
| | Silt clay | | 5 | | 5 |
| | Sandy loam | | 2 | | 2 |
| | Sandy | | 1 | | 1 |
| | Loam | | 2 | | 2 |

The result shows the different rainfall intensity in the study area. The rainfall map generated from the rainfall data from NIMET was rasterized using the "Inverse Distance Weight" IDW tool to cover the entire study area and reclassified into suitability rank. As shown in Table 7, area with high rainfall intensity have the highest suitability rank while areas with the low rainfall intensity have the lowest suitability rank for the study area. The rainfall map and the rainfall suitability map for both pond and dams are shown in Figure 20 and 21 respectively and the results shows that rainfall being one of the most important criteria for siting a rain water harvesting structure, is of highest intensity in the southeast regions of the study area.

Table 7: Suitability Ranking Score for Rainfall

| CRITERIA | CLASS | VALUE (DAM) | SCORE (DAM) | VALUE (POND) | SCORE (POND) |
|---|---|---|---|---|---|
| RAINFALL | | 2456 - 2717 | 1 | 2456 - 2717 | 1 |
| | | 2718 - 2856 | 2 | 2718 - 2856 | 2 |
| | | 2857 - 2969 | 3 | 2857 - 2969 | 3 |
| | | 2970 - 3079 | 4 | 2970 - 3079 | 4 |
| | | 3080 - 3259 | 5 | 3080 - 3259 | 5 |

The criteria used for the identification of potential RWH structures are equally important. However, different weights are assigned to the criteria. To develop weights, the Pair Wise Comparison within the Analytical Hierarchy Process (AHP), was applied by calculating the Consistency ratio (CR) using equation 2 to assess the consistency between the acquired experts' opinions and literatures to identify the final weights for each criterion. The result of the weight is shown in Table 8 below. The value of the Consistency Ratio (CR) value obtained was with the 0.1 for an acceptable pairwise comparison [21]. The Consistency Ratio (CR) value for Table 8 was 0.04 which was less than the accepted maximum value of 0.1. Hence the Consistency of the pairwise comparison is acceptable.

Table 8: Weight Value for the Criteria for RWH Structures

| Factors | Weight (%) |
|---|---|
| Rainfall | 41.8 |
| Slope | 31.7 |
| Soil texture | 15.9 |
| Landuse Landcover | 5.9 |
| Drainage | 4.7 |

Rainwater Harvesting Structures suitability maps was generated using multi criteria analysis and GIS, two RWH structure were selected in this study which area Dams and Ponds. The RWH structure were analysed separately to generate their final suitability map. The weighted overlay technique was used to generate the final suitability map. The suitability maps were classified into: not suitable, lowly suitable, moderately suitable, high suitable, and very high suitable

A suitability map for siting pond in the study area, illustrated in Figure 22, was generated showing the percentage coverage of the study area for each suitability level which are shown in Table 9.

Table 9: Percentage Coverage for Pond Suitability Level

| SUITABILITY LEVEL | % COVERAGE | AREA ($KM^2$) |
|---|---|---|
| Not Suitable | 0.83 | 55.1 |
| Lowly Suitable | 25.46 | 1697.5 |
| Moderately Suitable | 52.80 | 3519.5 |
| Highly Suitable | 19.85 | 1323.3 |
| Very Highly Suitable | 1.06 | 70.4 |

As illustrated in the Table 9 above, only 20.91% of the total study area falls within location of high and very suitable level for pond siting. For the sites area that met the condition, most of the site falls within area of high rainfall intensity and suitable soil type. On the other hand, unsuitable areas fall within the built-up area. It was also discovered that ponds are best cited in areas covering 1.06% which represents 70.4km2¬ (very highly suitable) of the total study area. These areas are in the Okobo, Mbo, Oron, Udung Uko and Ikot Abasi LGA regions of Akwa Ibom State.

A suitability map for siting dam in the study area, illustrated in Table 10, was generated showing the percentage coverage of the study area for each suitability level which are shown in Figure 23.

Table 10: Percentage Coverage for Dam Suitability Level

| SUITABILITY LEVEL | % COVERAGE | AREA ($KM^2$) |
|---|---|---|
| Not Suitable | 0.36 | 23.2 |
| Lowly Suitable | 8.48 | 565.2 |
| Moderately Suitable | 54.14 | 3609.0 |
| Highly Suitable | 35.14 | 2342.9 |
| Very Highly Suitable | 1.88 | 12.5 |

As illustrated in Table 10 above, only 37.02% of the total study area falls within location of high and very suitable level for Dam siting. Most of the site areas that met the condition falls within area of high rainfall intensity, suitable soil type and slope. From Table 10 and Figure 23 above, it is discovered that Dams are best cited in areas covering 1.88% which represents 12.5 km2¬ (very highly suitable) of the total study area. These areas are in the Okobo, Mbo, Oron, Udung Uko and Ikot Abasi LGA regions of Akwa Ibom State.

## 4. Conclusion

Today, RHS are very important for semi-arid geographical area in the world. But success of these systems mainly depends on identification of suitable sites and technology. However, the selection of appropriate sites for rainwater harvesting potential on large scales present great challenge. Integration of Remote Sensing and GIS techniques provide reliable, accurate and update database on land and water resources, which is a prerequisite for an integrated approach in identifying suitable sites for water harvesting structures.

From the results, it can be observed that ponds are best cited in areas covering 1.06% which represents 70.4km2¬ (very highly suitable) of the total study area. These areas are in the Okobo, Mbo, Oron, Udung Uko and Ikot Abasi LGA regions of Akwa Ibom State. While Dams are best cited in areas covering 1.88% which represents 12.5 km2¬ (very highly suitable) of the total study area. These areas are also in the Okobo, Mbo, Oron, Udung Uko and Ikot Abasi LGA regions of Akwa Ibom State.

The identification of rainwater harvesting sites is interdependent on various parameters like nature of terrain, runoff potential, hydrogeology, soil and drainage by using remote sensing and GIS technique. Again, the study area was classified into suitability for rainwater harvesting sites based on the number of parameters loaded using GIS integration and present study clearly shows the suitability of rainwater harvesting structures in the study area. This study best exemplifies the integrated approach of remote sensing and GIS in water resource development.

Potential zone identification for water harvesting structure has been done using AHP a multi criteria decision method. To generate the suitability maps the thematic layers, of all the criteria used for the suitability analysis were integrated with the weight overlay process using the weight generated by the pairwise comparison. The whole process prepared in ArcGIS was used to identify the probable zones in the Akwa Ibom State River watershed, south-south, Nigeria.

The percolation tanks, check dams, subsurface dyke, gully plug, etc., are suggested at suitable sites. Apart from this, the dug well recharge technique must be promoted in some areas of Akwa Ibom State to enhance the sustainability of improvement of agricultural practices in the region.

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