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Gis-Based Multi Criteria Model for Location of Rice Aggregation Centers in Anambra State

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Rice aggregation centers are tasked with checkmating substandard agricultural produce that are often encountered by the integrated millers during the course of buying from farm to farm to ensure already made market for their produce. Thus, it must be well placed to occupy strategic positions such that all different rice cultivating zones of the state get access to the facility. Given that these facilities will provide salient services, sets of demand points tasked with the provision storage, processing capability and a constant market for various rice farmers within the state. It is pertinent that these facilities are located properly considering all unique factors on ground. This study therefore aimed at a GIS-based multi criteria model for location of rice aggregation centers in Anambra State. The study was carried out using Geographical Information System (GIS) technology. Several GIS thematic layers were obtained and considered important factors in citing rice aggregation centers such as road network, Land Use and Land Cover (LULC), slope, river, cost distance, electricity network, floodplains, erosion plains and proximity to rice farms. It revealed optimal locations for siting a modular aggregation rice center at Nzam, Onoia, Aguleri, Nando, Akenu, Achalla, Ezira, Ndiokpalaeze, Ogbakuma and Uli. The goal throughout this study was to provide a reliable and complete analysis of siting modular rice aggregation centers in the agricultural zones in Anambra State. The approach and results obtained in this study are recommended as a spatial decision tool for site selection of modular rice aggregation centers in developing countries.

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Keywords: GIS; multi criteria model; location analysis; optimization; rice aggregation center.

1. INTRODUCTION

In Nigeria rice has consumption per capita of 32kg indicating 4.7% increase in the past decade making the total consumption to be 6.4 million tonnes in 2017 as against 3.7 million tonnes produced per year [1,2]. Rice (*Oryza sativa* L.) is fast becoming a major staple food for urban and rural consumers [3,4] of most sub-Saharan countries. Its domestic consumption in most African countries is significantly greater than production, thereby necessitating increased imports and drain of scarce foreign exchange. It is noteworthy that the demand for rice in sub-Saharan African (SSA) is double the rate of population growth while consumption is growing faster than production. Nigeria depends largely on imported rice to make up the deficit in rice supply and the rate of importation is increasing year by year at an alarming rate. Her total rice consumption in 2005 amounted to about 500,000 tons which is equivalent to per capita consumption of 22 kg per person [5]. The self-sufficiency ratio of rice in Nigeria has declined from 38% in 1999 to 24% in 2006 [6,7]. According to Michael and Ian [8], the production of premium quality rice has increased by approximately 0.5 million metric tons between the periods of 2009 and 2013.

Anambra state's smallholder farmers play an important role in agricultural production. Accounting for about 30-40 percent of total rice output and 70 percent of the marketed produce [9].

Smallholder rice cultivation as a key source of food, livelihoods and employment for many rural households in Anambra state is encumbered by various phases of challenges relating to storage, transportation, aggregation and sales of the harvested crops.

Anambra State being an industrial area has a very high demand of rice since its population is made up of 2,802,600 males and 2,725,209 females according to 2016 Population and Housing Census.

Modular rice Aggregation centers as well as the use of improved agricultural technologies are the major strategies and interventions required to improve rice productivity, ensure steady supply, food security and nutrition to meet food needs of the increasing population of the state. The aggregation centers serve to ensure constant and steady market for the farmers and at the same time checkmating millers' challenges of going from one farm to another before getting standard agricultural produce for processing, packaging , global market acceptability and nutritious rice grain; hence the problem of where to locate aggregation facilities.

There is need for an efficient analysis of various geographical criteria before siting a facility so important as the modular aggregation centers. These facilities should be so located such that there is maximum coverage towards generating a private sector driven grains cleaning centers that will mitigate the challenges of integrated millers as regards getting quality rice paddy and others for processing into standard products that will attract global market. It has to be situated such that there is efficient coverage of all the rice producing communities; large and small rice farms within the zones in the state and such that small holder farms get adequate access to the aggregation centers.

The efficiency in distribution/aggregation systems of rice aggregation centers is measured in terms of the ability to deploy units and personnel in a timely and effective manner upon an event's occurrence. Therefore, the application of geographical analysis procedures, oriented towards service planning through the use of Geographical Information Systems (GIS) is a very important factor for proper siting of aggregation centers in Anambra Agricultural zones.

Geographic information systems (GIS) is a tool used for spatial analysis by capturing, storing analyzing, displaying and outputting spatially referenced information. As such they play a big role in spatial decision making process. Recent development in field of decision making leads to dramatic improvements in the capabilities of GIS in location analysis. These developments are reviewed through analysis of attribute data especially procedures for Multi-Criteria and location analysis in GIS [10]. Jia et al. [11] emphasized on the importance of geographic information system (GIS) as tools for monitoring and planning purposes; thus quite suitable for designing the location modelling process.

According to Tali [12], GIS location modelling helps planners to locate facilities and also to support them in taking a decision about where to locate facility or facilities inside a chosen location.

Geographic information systems are used in conjunction with other systems and methods such as systems for decision making (DSS) and the method for multi-criteria decision making (MCDM) [10]. Synergistic effect, generated by combining these tools contribute to the efficiency and quality of spatial analysis for industrial site selection [13,14]. One of the main problem of facility selection is that it requires a lot of time for decision making, because of the number of factors to be considered for quality analysis [15,16]. To speed up decision process, it is necessary to develop a model for decision making that is optimized and adapted for a site selection problem such as this. Therefore, the aim of this study is to depict the best location for the rice aggregation centers for the outlying rice fields of agricultural zones in Anambra State Nigeria using a GIS-based multi criteria analysis.

2. MATERIALS AND METHODS

2.1 Study Area

The study area, Anambra state is located between Latitude 6° 20' 00" N and Longitude 7° 00' 00" E. The state covers a land mass of about 4,416 square kilometer and contains a cluster of numerous thickly populated villages and small towns, giving the area an estimated average density of 1,500–2,000 persons per square kilometer. The Capital of Anambra State is Awka while Ayamelum, Anambra East , Anambra West, Awka North, Ogbaru, Ihiala, Orumba North and Orumba South are the biggest commercial rice locations. Boundaries are formed by Delta State to the west, Imo State and Rivers State to the south, Enugu State to the East and Kogi State to the North.

The origin of the name is derived from the Anambra River (Omambala) which is a tributary of the famous River Niger. Anambra state comprises 21 Local Government Areas (LGAs) which are broadly divided into four agricultural zones (namely: Aguata, Anambra, Awka and Onitsha). Fig. 1 below shows; Map of Anambra state showing LGAs for rice production.

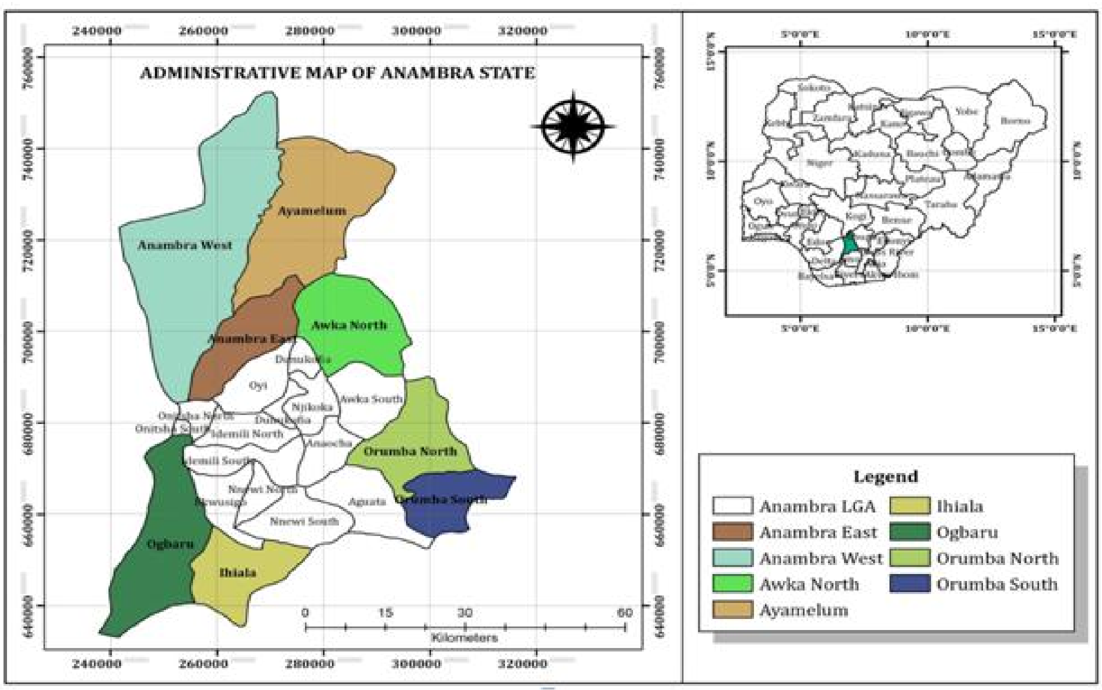


Fig. 1. Map of Anambra State showing LGAs for Rice Production

The study area lies within the Anambra Basin and it is made up of Enugu Shale, Mamu Formation, Ajali Sandstone, and Nsukka Formation. The four agricultural zones of the state have one geologic characteristic in common which is the fact that they have underlying impervious clay shales which cause water logging of the soil during rainy season. The Aguata zone is uniquely underlain by a geological formation – the Nanka Sandstones. The two geologic formations underlying Awka zone are the Imo Shale and Ameki Formation. In the riverine and low-lying area particularly the plain west of Mamu River as far as to the land beyond the permanent site of Nnamdi Azikiwe University.

Anamb state is found in the Tropics, where the climate is seasonally damp and very humid. Its vegetation is predominantly grassland, with scattered forests and woodland areas of the tropical rain forest. It comprises tall trees with thick undergrowth and numerous climbers, [17].

The natural vegetative cover that exist in the agricultural zones are governed by the combined effects of temperature, humidity, rainfall and particularly, the variations that occur in the rainfall.

2.2 Data Collection and Sources

The major data used for this study came from field visits; these include: GPS coordinates of Rice farms in Anambra state. ArcGIS 10.5, Erdas Imagine, Microsoft Excel 2016, and Microsoft Word 2016; these software were used for analyzing the study. Other data were obtained from Landsat 8 OLI image covering the study area and SRTM DEM of the study area (www.earthexplorer.usgs.gov, 2018). The Rivers, Power lines and Road shape files of the study area were obtained from the GIS LAB, Department of Surveying and Geoinformatics, Nnamdi Azikiwe University (NAU), Awka.

2.3 GIS based Models

Open space planning is a type of facility planning; and GIS as well as location-allocation models has been extensively used in facilities planning. There are in fact three main GIS methods in facilities planning. These are the;

2.3.1 Buffer Zones method

This method draws buffers around existing facilities proportional to the latter's size and capacity. It finds holes in the urban areas which cannot be served by the existing facilities. This method does not take into consideration the distribution of population, nor does it consider whether the land identified is suitable for the facility or not.

2.3.2 Allocation method

This is a method in which population in a network is allocated to the closest known or planned facility. This is similar to the buffer zone method but it takes population distribution into consideration. However, it requires data to be available in a network which is often not available in a GIS database.

2.3.3 Land suitability analysis

Land Suitability Analysis is one of the most commonly used spatial analysis functions in GIS. It identifies sites according to their suitability for the location of facility under a set of criteria. The first two methods are often combined with the third method. Suitable sites are first identified by Method 3 (land suitability analysis), and they are then evaluated by using either Method 1 (buffer zones) or Method 2 (allocation method). But, these GIS methods do not guarantee the optimal location of facilities.

By contrast, location-allocation (LA) models can be used to find the optimal location of facilities.

2.4 Image Enhancement and Classification

Image enhancement was performed to improve the quality of the image. This process was done to edit the original image data by increasing the amount of information for visual interpretation from the data to create "new" image. Band combination was used for this study; this technique is most useful because many satellite images when examined on a band by band display give inadequate information for image interpretation. The appropriate RGB bands of the Landsat image were merged to obtain a false color composite, using band 7 (shortwave infrared), band 5 (near infrared) and band 2 (blue). After which a classification scheme was developed for the study area after Anderson et al. [18] followed by image classification. In this study, the Landsat 8 image was classified using the supervised classification method in the ArcGIS software.

2.5 Selection and Derivation of Datasets

Selection and derivation of the criteria for the siting of rice modular aggregation centers was achieved based on guidelines from Food and Agriculture Organization and Environmental Impact Assessment Act (EIA) on the siting of modular centers, (Veldkamp, 2004). The following criteria (factors/constraints) (Table 1) were used in this study. Constraints in this study indicate areas where developments are forbidden either by local / governmental laws or natural hazard prone areas, in this case offset distances from these areas such as floodplains, water bodies, erosion prone areas were considered and set as constraints.

Based on the criteria selected, the data used for this study were assembled. Land cover/landuse was extracted from Landsat 8 image, slope, flood and erosion plains were extracted from the SRTM and cost distance from slope. The distance to roads, distance to electricity network, proximity to rice farms were derived using Boolean distance algorithm. The slope was required to be between slope angles of 8% and 15% to enable the ease of construction and maintenance of the aggregation centers. The distance from road networks should be at least 1km from the rice farms this is because the cost of rice transportation is dependent on the proximity of the rice farms to both the aggregation centre and major roads. The landcover/landuse space for the aggregation centers is required to be on barren land, shrub or open spaces, as the knowledge of landcover/landuse is important for planning, it is considered to be an essential element for modelling and deciding suitable areas and protected areas to be avoided. In terms of electricity, aggregation centers should not be located further than 1km from power lines this is to reduce the cost of connecting the centers to electricity. The least cost distance and distance to rice farms from the aggregation centers should be on the least cost area/routes and at least 2.5km to and from the rice farms, this is to allow for better economization and cost efficiency when delivering the rice from the farms and to the markets. In terms of water bodies, the aggregation centers should be located 2.5km away from water bodies and cannot be sited on wetlands, this is to avoid ecological sensitive areas as well as avoiding water pollution. Floodplains and erosion plains are also avoided by cutting out a distance of 2.5km away from flood and erosion planes to reduce flood and erosion vulnerability when citing the aggregation centers.

2.6 Reclassification and Standardization of Datasets

Reclassification and standardization of criteria was done to standardize the criteria to a common measurement system that represents a relative weighting scale that permits the analysis to be completed freely between the datasets and show the suitability level for each of the standardized criteria. For this study, all the datasets were reclassified into four: for high suitability, moderate suitability , low suitability and no suitability. The initially derived dataset were categorized into floating and continuous type and there was a need for them to be reclassified so that each range of value can be assigned one discrete integer value such as 1, 2, 3 and 4 according to the measurement scale. This is because the inputs of the weighted overlay must contain discrete integer values, see Fig. 2 for the reclassified layers.

2.7 Pairwise Comparison and Computation of Criterion Weights

In this study, the pairwise comparison method was adopted to assign weights to each criterion. This method provides an organized structure for group discussions and helps the decision-making group focus on areas of agreement and disagreement when setting criterion weights. Saaty [19] proposed the pairwise comparison method in the context of the analytical hierarchy process. This method is an effective method for the determination of relative importance. The method uses a ratio matrix to compare one criterion with another. The matrix of pairwise comparisons represents the intensities of the expert's preference between individual pairs of criteria. They are usually chosen according to a given scale ranging from 1 to 9 for a given 'n' number of criteria, where 1 represents criteria of equal importance and 9 represents a criterion with extreme importance compared to the other.

The weights for the nine criteria were determined as shown in Table 2. The judgment table (comparison matrix) was represented by a 9 x 9 matrix and then multiplied by itself to obtain eigenvectors. Suppose that landuse is extremely important over the slope attribute; that is the comparison result is a value of 9. Further, suppose that landuse is moderately important preferred to distance to road then a numerical score of 3 is assigned. Finally, consider another pairwise comparison, which is slope compared to proximity to rice farmlands and suppose that the latter is strongly preferred to the former, then a score of 8 is assigned. These scores are places in the upper right corner of the pairwise comparison matrix, see Table 3 for the comparison matrix calculated.

To compute for criterion weights, the sum of the values in each column of the pairwise comparison matrix (Table 3), followed by dividing each element in the matrix by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix) then finally, computing the average of the elements in each row of the normalized matrix, that is, divide the sum of normalized scores for each row by 9 (the number of criteria). These averages provide an estimate of the relative weights of the criteria being compared. Using this method; the weights are interpreted as the average of all possible ways of comparing the criteria, See Table 4.

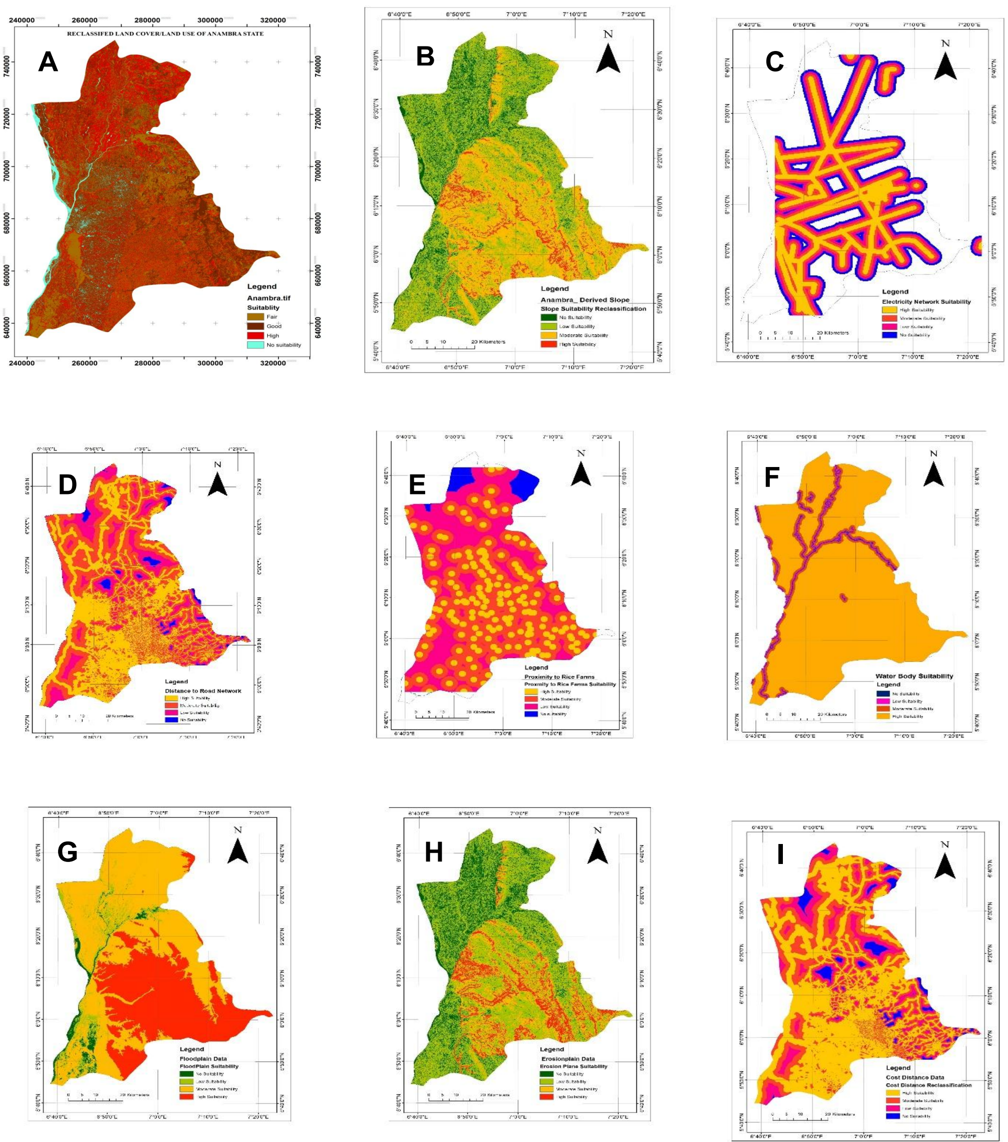


Fig. 2. (A) Landcover/landuse layer, (B) Slope layer, (C) Distance to Electricity network layer, (D) Distance to road network layer, (E) Distance to rice farms, (F) Distance to waterbody, (G) Floodplain layer, (H) Erosion plain layer and (I) Cost Distance layer

Table 1. Criteria (Factors/Constraints)

S/N	Criterion	Factor/ Constraint	Requirement for suitability	Reason for Selection	Original Data Structure	Resolution / Feature Type
1	Slope	Factor	Should have slope angles between 8% and 15%	Slope affects the ease of construction and maintenance	Raster	30m
2	Transportation network	Factor	Should be at least 1km from the rice farms.	Cost of rice transportation is dependent on the proximity of the rice farms to the aggregation centre.	Raster	Polygon
3	Land Cover/ Land Use	Factor	Must be barren land, shrub or open spaces	Knowledge of landcover/landuse is important for planning, it is considered to be an essential element for modelling and deciding suitable areas and protected areas to be avoided.	Raster	30m
4	Distance to Electricity Network	Factor	Must not be located further than 1km from Power lines	Reducing the cost of building new transmission lines	Vector	Polygon
5	Least Cost Distance	Factor	Must be located on the least cost area/route to and from the rice farms	Allowing for better economization and cost efficiency	Vector	Polygon
6	Distance to Water Bodies	constraint	Must be located 2.5km away from waterbodies and cannot be sited on a wetland	Avoiding ecological sensitive areas as well as avoiding water pollution	Vector	Polygon
7	Floodplain	Constraint	2.5km away from floodplains	Reducing flood vulnerability.	Vector	Polygon
8	Erosion prone areas	Constraint	2.5km away from Erosion Prone Areas	Reducing erosion vulnerability.	Vector	Polygon
9	Proximity to Rice farms	Factor	2.5km within Rice Farms	Reducing the cost of transporting rice from the farms to the aggregation centers	Vector	Polygon

Table 2. Scale for Pairwise Comparison, Saaty [19]

Intensity of importance	Definition
1	Equal importance
2	Equal to moderate importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

Table 3. Pairwise comparison matrix

Criterion	Landcover /Landuse	Proximity to farmland	Distance to Road	Cost Distance	Distance to Waterbody	Distance to Transmission Line	Distance from floodplains	Distance from Erosion plains	Slope
Landcover /Landuse	1	2	3	4	5	5	5	6	9
Proximity to farmland	½	1	3	4	5	5	5	6	8
Distance to Road	1/3	1/3	1	3	4	5	5	6	7
Cost Distance	¼	¼	1/3	1	2	3	4	5	7
Distance to Waterbody	1/5	1/5	¼	½	`1	2	3	4	6
Distance to Transmission Line	1/5	1/5	1/5	1/3	½	1	3	5	8
Distance from floodplains	1/5	1/5	1/5	¼	1/3	1/3	1	3	6
Distance from Erosion plains	1/6	1/6	1/6	1/5	¼	1/5	1/3	1	5
Slope	1/9	1/8	1/7	1/7	1/6	1/8	1/6	1/5	1
Total	2.96	4.47	8.29	13.42	18.25	21.65	26.5	36.2	57

Table 4. Normalized pairwise comparison matrix

Criterion	Landcover /Landuse	Proximity to farmland	Distance to Road	Cost Distance	Distance to Waterbody	Distance to Transmission Line	Distance from floodplains	Distance from Erosion plains	Slope	Relative Weight
Landcover /Landuse	0.33	0.44	0.36	0.29	0.27	0.05	0.18	0.16	1.11	0.35
Proximity to farmland	0.16	0.22	0.36	0.29	0.07	0.05	0.18	0.16	0.14	0.18
Distance to Road	0.11	0.07	0.12	0.22	0.21	0.05	0.18	0.16	0.12	0.14
Cost Distance	0.08	0.05	0.04	0.07	0.10	0.13	0.15	0.13	0.12	0.10
Distance to Waterbody	0.06	0.04	0.03	0.03	0.05	0.09	0.11	0.11	0.10	0.07
Distance to Transmission Line	0.06	0.04	0.02	0.02	0.02	0.04	0.11	0.13	0.14	0.06
Distance from floodplains	0.06	0.04	0.02	0.01	0.01	0.01	0.03	0.08	0.10	0.04
Distance from Erosion plains	0.05	0.03	0.02	0.01	0.01	0.009	0.01	0.02	0.08	0.03
Slope	0.03	0.02	0.01	0.01	0.009	0.005	0.006	0.005	0.01	0.01

2.8 Estimation of Consistency Ratio and Suitability Calculation

The value of pairwise comparison relies on subjective judgment which might lead to arbitrary result which could be bias. A numerical index, called consistency ratio (CR) is used for evaluating the consistency of pairwise comparison matrix (Saaty 1990). The index indicates the ratio of the consistency index (CI) to the average consistency index, which is also called Random Index (RI). This is given as:

CR = Consistency index (CI)/Random Consistency Index (RI)
The value of Random Consistency Index (RI) can be found in the table, prepared according to number of criteria involved (Saaty, 1990), as shown in Table 5.

The value of Consistency index, CI can be calculated from the preference matrix according to equation below

$$CI = \frac{\lambda\text{max} - \text{n}}{\text{n} - 1}$$

λmax = the Principal Eigen Value; n = the number of factors
λmax = Σ of the products between each element of the priority vector and relative weights in Tables 3 and 4 respectively
λmax = 9.59
by substituting the values we have;
CI = 0.073
According to [19] in Table 5; consistency Index was gotten to be
CR = 0.05
CR = 0.05 < 0.10 (Acceptable)

The consistency ratio (CR) is designed in such a way that if CR<0.10, the ratio indicates a reasonable level of consistency in the pairwise comparisons; if, however, CR ≥ 0.10, the values of the ratio are indicative of inconsistent judgments. From the judgment a Consistency Ratio (CR) of 0.05 was achieved which was less than the maximum allowable ratio of 0.10. Following this, the weighted sum analysis was calculated in ArcGIS 10.5 with each of the layers weighted (Landcover/landuse 35%, Proximity to rice farmland 18%, Distance to Road 14%, Cost Distance 10%, Distance to waterbody 7%, Distance to transmission line 6%, Distance from floodplains 4%, Distances from erosion plains 3% and Slope 1%). The high suitable areas were extracted from the output raster and were converted to points to determine and select suitable point locations for the modular rice aggregation centers after which a ground truth survey was carried out to account for conformity of the result on what was obtainable on the ground and thereby determining its reliability.

3. RESULTS AND DISCUSSION

The high suitable areas were extracted from the output raster and was converted to points to determine and select suitable point locations for the modular rice aggregation centers, this enabled the extraction of the coordinates of the located aggregation centers (see Fig. 3).

From the suitability map (Fig. 1), and subsequent ground truth carried out, it was important to note that previously Ayamelum had 4 out of 7 of the total aggregation centers in Anambra state making it the zone with the highest concentration of aggregation centers to a total number of 163 rice farms. The aggregation centers in Ayamelum in its service zone to the rice farms covers a minimum distance of 700m, maximum distance of 12.7km and a mean distance of 6.7km. Anambra west had no aggregation centre with 20 rice farms.

Anambra East has one aggregation centre to a total of 18 rice farms, with a service zone that covers a minimum distance of 7.7km, maximum distance of 16km and a mean distance of 11.85km from the rice farms. Awka North has one aggregation centre to a total of 33 rice farms, with a service zone that covers a minimum distance of 2.3km, maximum distance of 12.5km and a mean distance of 7.4km from the rice farms. Ihiala, Orumba North and Orumba South also had no aggregation centre to service a combined total of 92 rice farms. Ogbaru has one aggregation center to a total of 60 rice farms, with a service zone that covers a minimum distance of 4km, maximum distance of 9.9km and a mean distance of 6.9km from the rice farms. See Fig. 4.

Table 5. Random consistency index

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

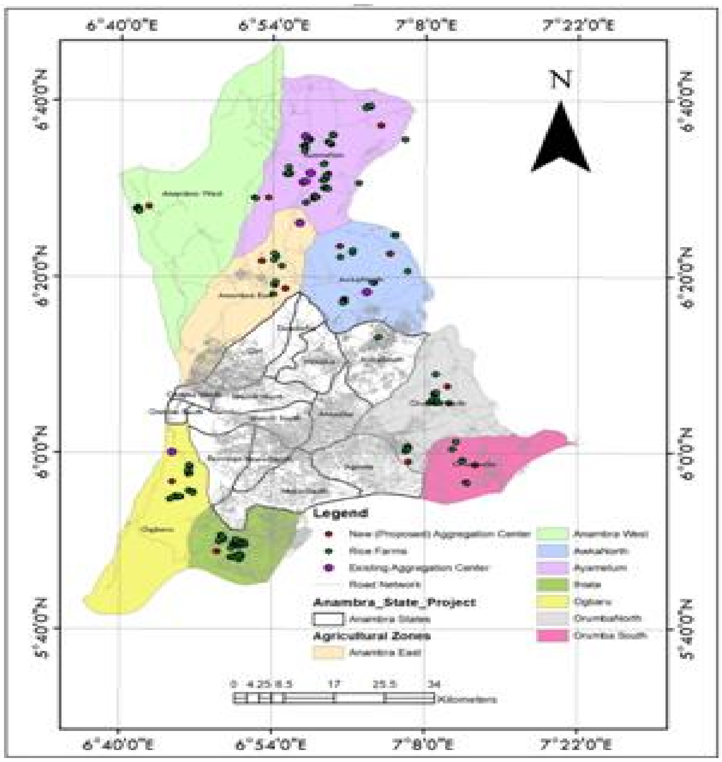
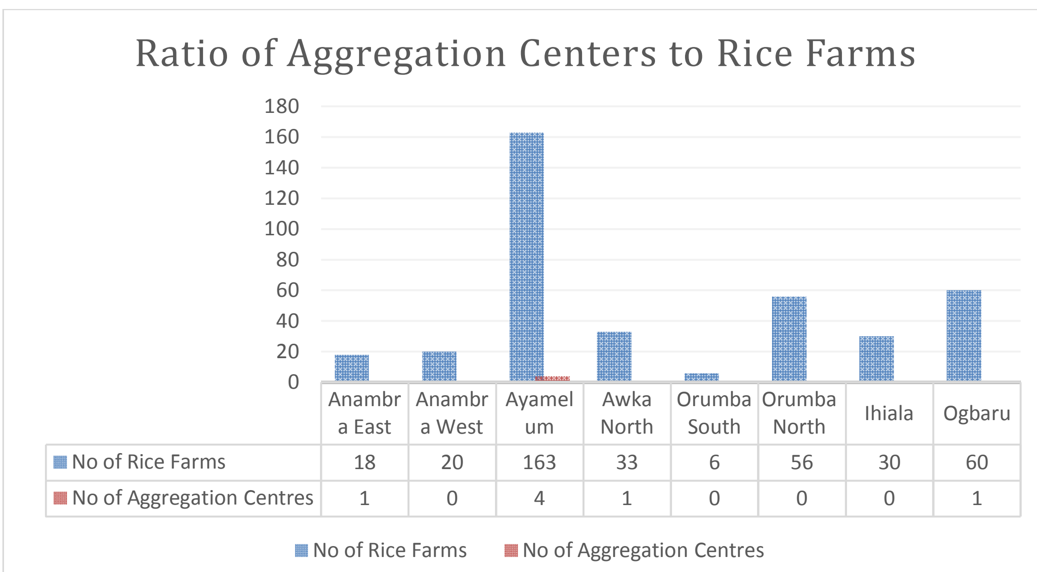


Fig. 3. Located Aggregation Centers in Anambra State Agricultural Zones



	Anambra East	Anambra West	Ayamelum	Awka North	Orumba South	Orumba North	Ihiala	Ogbaru
No of Rice Farms	18	20	163	33	6	56	30	60
No of Aggregation Centres	1	0	4	1	0	0	0	1

Fig. 4. Ratio of Aggregation centers to Rice Farms in Anambra agricultural zone

Also, the results obtained from the analysis proposed two locations in Ayamelum in addition to the existing centers bringing it to a total of 6 aggregation centers. The aggregation centers in Ayamelum both the existing and the proposed have a service zone of a minimum distance of 700m, maximum distance of 4.9km and a mean distance of 2.8km. Anambra West which previously had no aggregation centre was proposed one aggregation location having a minimum distance of 1.7km, maximum distance of 2.4km and a mean distance of 2km.

Anambra East which also had one aggregation centre to a total of 18 rice farms was proposed two aggregation centers that covers a minimum distance of 1.9km, maximum distance of 3.4km and a mean distance of 2.65km from the rice farms. Awka North was also proposed two aggregation locations with a service zone that covers a minimum distance of 2km, maximum distance of 4.6km and a mean distance of 3.3km from the rice farms. Orumba North which previously had no centre, was proposed two aggregation locations with a service zone that covers a minimum distance of 2.3km, maximum distance of 4.6km and a mean distance of 3.4km from the rice farms. Also, Orumba South which previously had no centre, was proposed one aggregation location with a service zone that covers a minimum distance of 2.4km, maximum distance of 5.8km and a mean distance of 4.1km from the rice farms. Ihiala, had no aggregation centre to a total of 30 rice farms, and was also proposed an aggregation location with a service zone that covers a minimum distance of 1.7km, maximum distance of 5.5km and a mean distance of 3.6km from the rice farms. Ogbaru previously had one aggregation centre to a total of 60 rice farms, and was also proposed an aggregation location with a service zone that covers a minimum distance of 3.1km, maximum distance of 4.5km and a mean distance of 3.8km from the rice farms, see Fig. 4.

Also, comparing the mean distances from the rice farms to the existing aggregation centers and the mean distances from the rice farms and the proposed distances, it can be seen that the mean distances has been reduced and optimized by the proposed locations, this is seen in Anambra East which had a previous mean distance of 7.7km optimised to 2.6km by increasing the number of aggregation locations and applying the shortest route network analysis to reduce the distance travelled when going from the farms to an aggregation location. This is also seen in Ayamelum, Awka North and Ogbaru, the mean distances from the farms to the aggregation locations have been optimized from 6.7km to 2.8km, 7.6km to 3.3km and 6.9km to 3.8km respectively. The mean distances from zones which previously had no aggregation centers (Anambra West, Orumba North, Orumba South, and Ihiala) were also optimized to realize the suitable locations for aggregation centers in proximity to the rice farms, see Fig. 5.

Having satisfied all criteria by weighted linear combination, the potential locations for aggregation rice centers in the eight agricultural zones in Anambra state are located at Nzam, Onoia, Aguleri, Nando, Akenu, Achalla, Ezira, Ndiokpalaeze, Ogbakuma and Uli, see Table 6. for more details.

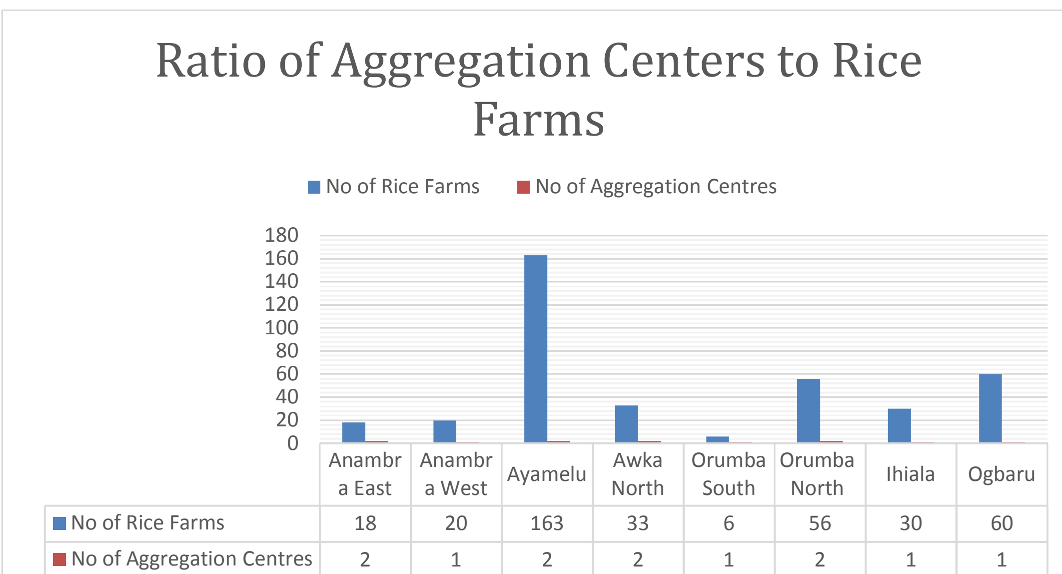


Fig. 5. Ration of Proposed aggregation locations to rice farms in Anambra agricultural Zone

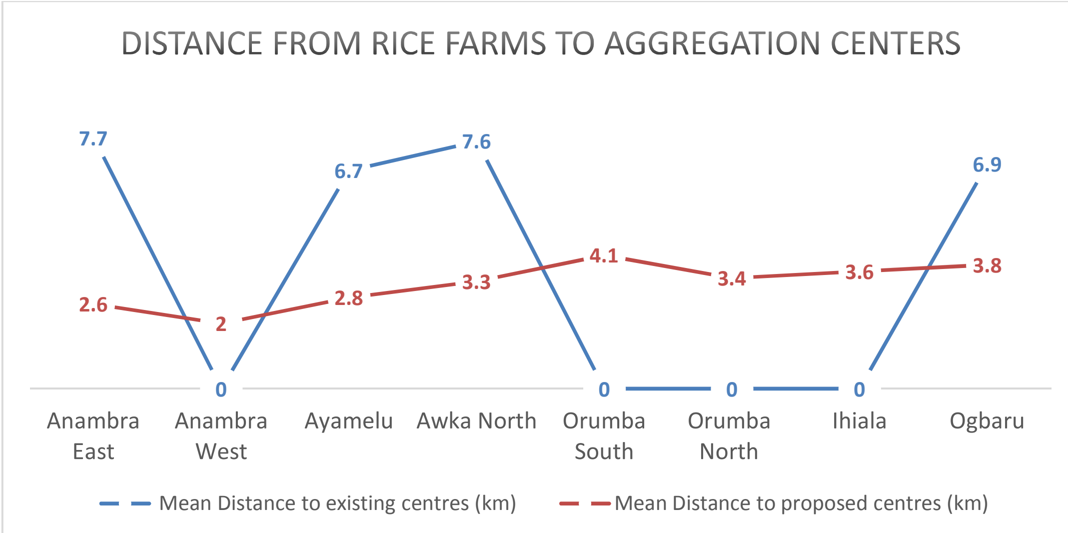


Fig. 6. Mean distances from rice farms to existing and proposed aggregation centers

Table 6. Proposed locations for siting rice aggregation centers in the agricultural zones

ID	Easting(m)	Northing(m)	LGA	Locality
1	246650.072	715444.887	Anambra West	Nzam
2	266945.383	717166.913	Ayamelum	Onoia
3	265838.366	703882.710	Anambra East	Aguleri
4	269774.426	698101.621	Anambra East	Nando
5	287561.807	705345.575	Awka North	Akenu
6	278999.568	706957.757	Awka North	Achalla
7	285982.481	732224.043	Ayamelum	Ifite Ogwari
9	297203.847	677560.307	Orumba North	Ajali
10	301877.918	661078.054	Orumba South	Ezira
11	290561.745	661816.065	Orumba North	Ndiokpalaeze
12	250586.133	657757.003	Ogbaru	Ogbakuma
13	258093.616	643112.254	Ihiala	Uli

4. CONCLUSION

Modular rice aggregation center selection can be accomplished by spatial decision; spatial decisions typically involve a large set of feasible alternatives. GIS has demonstrated its effectiveness through the use of remotely sensed data in providing the necessary spectral and spatial information for generating information layers for modular rice aggregation site selection criteria. The GIS as a decision-making tool, being facilitated, combined various information layers as well as implementing the necessary analysis on the data, although the GIS methodology makes the decision-making process more objective, there is still an element of subjectivity associated with the allocation of map weights and scaling. This also allows flexibility to the planners to incorporate varying degree of importance to each criterion based on their experience.

The study was able to apply spatial decision making in using the different criteria available to ascertain where modular rice aggregation centers can be located within Anambra State. The study located thirteen sites satisfying all siting criteria where modular rice aggregation centers can be sited with all sites exhibiting the best balance between all established criteria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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