Determination of Optimized Locations for Modular Rice Paddy Aggregation Centres in Anambra State, Nigeria by GIS-Based Approach

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ABSTRACT---- ***In this study an attempt was made to appraise the adequacy of the existing number and Locations of Rice aggregation centres (RAC) in the state and propose optimal numbers and their locations in the eight agricultural zones of Anambra state, Nigeria using Geographic Information System (GIS) methodology. This method involves spatial decision, which deals with a large set of feasible alternatives through the use of remotely sensed data in providing the required spectral and spatial information for generating information layers for rice aggregation centres selection criteria. The study discovered thirteen sites fulfilling all sitting criteria for location of rice aggregation centres. The results propose that two locations be allotted to Ayamelum in addition to the 4 existing centres, thereby bringing it to a total of 6 aggregation centres with a mean distance of 2.8km. Anambra East which had one aggregation centre was allocated 2 aggregation centres with a mean distance of 2.65km from the rice farms. Anambra West which previously had no aggregation centre was allocated one aggregation centre with a mean distance of 2km. Awka North was also allocated two aggregation centres with a mean distance of 3.3km from the rice farms. Orumba South which previously had no centre was proposed one aggregation centre with a mean distance of 4.1km from the rice farms. Orumba North which previously had no centre was allocated two aggregation centres with a mean distance of 3.4km from the rice farms. Ihiala, had no aggregation centre but was allocated 1 aggregation centre which has a mean distance of 3.6km from the rice farms. Ogbaru previously had one aggregation centre but was allocated 1 more aggregation centre with a mean distance of 3.8km from the rice farms. These results have shown that GIS-based location modelling can be successfully used in locating agro-service centres such as products aggregation centres.***

Keywords: Rice, GIS, aggregation centres, Location, Modelling, optimization

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1. INTRODUCTION

Rice (*Oriza sativa*), is one of the tropical crops cultivated in almost all parts of Nigeria. It is one of the priority crops which have attracted the attention of the Federal government in her pursuit of food security. According to Okpala et al, (2021), Nigerian agricultural sector is undergoing series of reformation that will help to stabilize food security in the country. To achieve this, a lot of resources have been invested in rice production aimed at reaching self sufficiency. The result is that local rice production rose from about 5.4m metric ton in 2015 to 9m metric ton in 2021. This was achieved by interventions from IDA support to National Third FADAMA Development Project (NFDP–III), IFAD/FGN Support for Value Chain Development Programme (VCDP) and Anchor Borrower's Programme (ABP) by Central Bank of Nigeria (CBN), which has reduced the importation of rice (Emefiele, 2022). The intervention has built a sustainable framework for financing smallholder farmers in Nigeria and had also helped to reduce Nigeria's import bill from countries like Thailand. For instance, Nigeria in 2014, imported 1.3 million metric tons of rice from Thailand. In 2016, rice importation from Thailand had fallen to only 58,000 metric tons, while at the end of 2021, Thailand only exported 2,160 metric tons to Nigeria. This has reduced rice importation from Thailand, thereby increased the rural economy and built a sustainable framework for financing smallholder farmers in Nigeria (Emefiele, 2022). In all these, Nigeria is yet to attain self-sufficiency in production of rice since supply is yet to meet demand (Okpala et al, 2021_b). Smallholder farmers in Anambra state play an important role in agricultural production; resulting in about 30-40 percent of total rice output and 70 percent of the marketed produce (Julia and Martina 2020; Okpala et al, 2021_a). Smallholder rice agriculture as a main source of food, livelihoods and employment for many rural households in Anambra state is overloaded by numerous 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 with its population of 2,802,600 males and 2,725,209 females according to 2016 Population and Housing Census.

Modular rice Aggregation centres as well as the use of improved agricultural technologies are the major strategies and programmes engaged by Anambra state government to cope with the projected increase in production from its rice project. The aggregation centres 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 a necessity for an efficient analysis of various geographical criteria before sitting a facility as important as the modular aggregation centres. These facilities should be so situated as to serve both farmers and millers. One of the major objectives is to guarantee high quality rice paddy for processing into products that will pass global market standards. It has to be positioned such that there is effective coverage of all the rice producing communities; large and small rice farms within the agricultural zones in the state and such that small holder farms will have sufficient access to the aggregation centres for easy evacuation of their produce. The efficacy in the delivery/aggregation systems of rice aggregation centres is measured in terms of the ability to deploy equipment and personnel in a timely and effective manner. Therefore, the application of geographical analysis procedures, leaning towards service planning through the use of Geographical Information Systems (GIS) is a very apt for proper sitting of aggregation centres in the Agricultural zones. GIS is an instrument used for spatial analysis by capturing, storing, analyzing, displaying and outputting spatially referenced information. As such they play a great role in spatial decision making process. Recent growth in field of decision making leads to dramatic improvements in the capabilities of GIS in location analysis. These growths are reviewed through analysis of attribute data especially procedures for Multi-Criteria and location analysis in GIS (Rikalovic et al., 2014; Okpala et al. 2021_a). Jia et al. 2011 and Okpala et al. 2021a highlighted the importance of GIS as tools for monitoring and planning purposes and recommended it as quite appropriate for location modelling.

According to Tali et al. (2017), GIS location modelling aids planners to locate facilities and also to support them in taking a decision about where to locate facility or facilities inside a chosen location. This technique is used in conjunction with other systems and methods such as systems for Decision Support Ssystem (DSS) and the method of multi-criteria decision making (MCDM) (Rikalovic et al. 2014, Okpala et al. 2021_a). Synergistic effect, generated by combining these tools contribute to the efficiency and quality of spatial analysis for industrial site selection (Malczewski ,2006; Khalid, 2013; Okpala et al. 2021_a). One of the chief problems 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 (Fataei and Mohammadian .,2015 ; Sarath et al. ,2018). To hasten decision process, it is often necessary to develop models for decision making that can be optimized and adapted to the selection problem.

Anambra State has a very high demand for rice, which is predominantly supplied by Small holder rice farmers. Rice production constitutes a major means of livelihood and employment for many rural dwellers. These small hold farmers supply the Modular rice Aggregation centres from where the subsequent value chains take off because they stop at production. There are, however, some challenges which are encountered by these off-takers in coordinating the collection of the paddy from the small holder farms scattered across the agricultural zones of the state. This inefficiency is attributed to inadequate information on the location and distribution of the farmers in the state. The major objective of this study, therefore, is to carry out a GIS-based analysis of the rice fields in Anambra state in order to determine the optimal locations of rice aggregation centres for efficient operations and cost effectiveness.

2. MATERIALS AND METHODS

2.1 Study Area

Anambra state is one of the 36 states in Nigeria located between Latitude 6° 20' 00" N and Longitude 7° 00' 00" E. It is the eighth-most populated state in the Federal Republic of Nigeria and the second-most densely populated state in Nigeria after Lagos State. The state covers a land mass of about 4,416 square kilometres 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 kilometre. It is one of the 5 states in South-Eastern Nigeria. The Capital and the Seat of Government is Awka in Awka-south Local Government Area (LGA). The state comprises 21 LGAs which are broadly divided into four agricultural zones namely: Aguata, Anambra, Awka and Onitsha Agricultural zones. It has boundaries with 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 Figure 1 below shows, Map showing rice-producing LGAs.

The geology of 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. Anambra state is located 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, UN-HABITAT, (2009). 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.

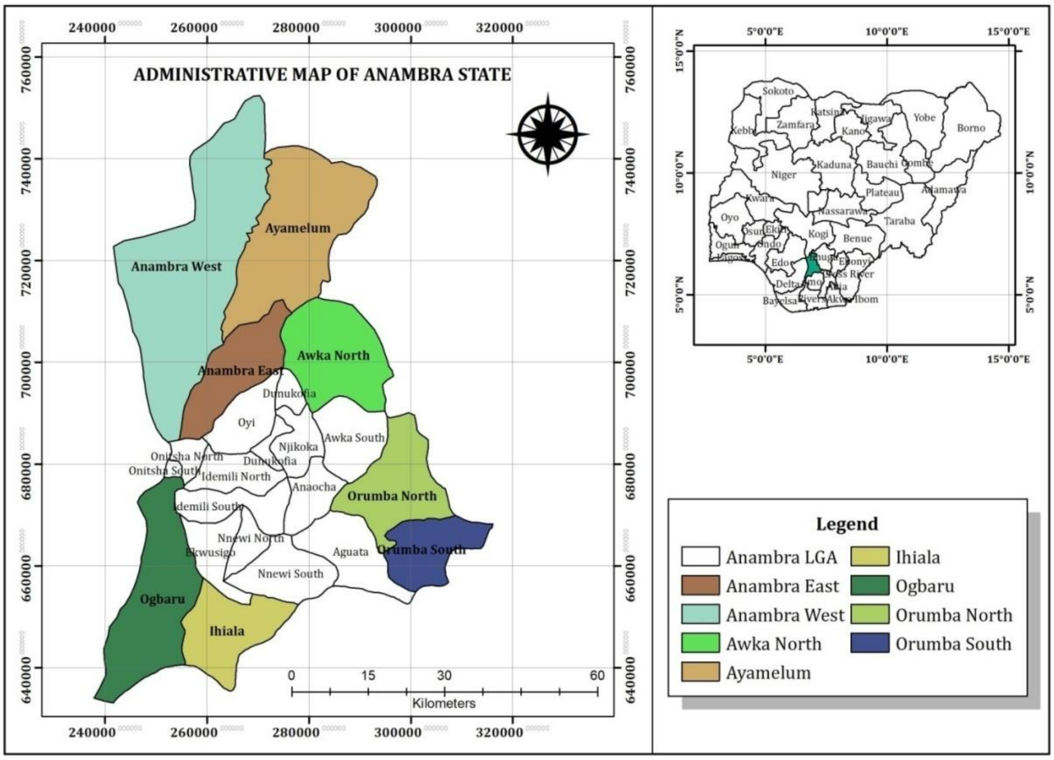

Figure 1: Map of Anambra state showing Rice-Production LGAs

2.2 Data Collection and Sources

To identify modular rice aggregation centres within agricultural zones of the state using GIS-Based approach, field visits were made to collect GPS coordinates of Rice farms in agricultural zones in Anambra states. ArcGIS 10.5, Erdas Imaging, Microsoft Excel 2016 software were used for data acquisition and analyses. Other data covering the study area were obtained from Landsat 8 OLI image and SRTM DEM (www.earthexplorer.usgs.gov, 2018). The shape files for Rivers, Power lines and Road network of the study area were obtained from the GIS LAB, Department of Surveying and Geoinformatics, Nnamdi Azikiwe University (NAU), Awka.

2.3 GIS-Based Modelling

A GIS-Based Analytical Hierarchy Process (AHP) model was used to obtain relative weights. This was done using the Weight Linear Combination (WLC) based on the reclassified dataset obtained from the GIS applications (buffer zones method, Allocation method and land suitability method) to locate the suitable sites for sitting the aggregation centres.

GIS based Location Modelling

GIS and location-allocation models used in facilities planning involving open space planning were extensively used in this study. The three main GIS approaches include: Buffer Zones method, Allocation methods, Land suitability analysis.

2.3.1 Buffer Zones method

This method draws buffers around existing facilities proportional to its 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 colour 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.

2.4 Selection and Derivation of Datasets

The criteria for the sitting of rice modular aggregation centres was achieved based on the Selection and derivation guidelines from Food and Agriculture Organization (FAO) and Environmental Impact Assessment Act (EIA) on the sitting of modular centres, (Veldkamp, 2004; Okpala et al. 2021_a). The following criteria (factors/constraints) as shown in (Table 1) were used in this study. This study indicated areas where developments are forbidden either by local / governmental laws or natural hazard prone areas as Constraints, in words, offset distances from these areas such as floodplains, water bodies, erosion prone areas were considered as constraints. Based on the criteria selected, the data used for this study were collected. Land cover/land use 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 centres. 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 land cover/land use space for the aggregation centres is required to be on barren land, shrub or open spaces, as the knowledge of land cover/land use is important for planning and is considered to be an essential element for modelling and deciding suitable areas and protected areas to be avoided. In terms of electricity, aggregation centres should not be located further than 1km from power lines this is to reduce the cost of connecting the centres to electricity. The least cost distance and distance to rice farms from the aggregation centres 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 centres 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 sitting the aggregation centres.

Data Acquisition

The data for this study were acquired using the following:

i. GPS Coordinates of Rice Farms in Anambra State, GPS Coordinates of the existing Aggregation Canters, Landsat 8 OLI covering the study area, STRMDEM of the study area (River, Power line and Road shape files of the study area)
ii. Hardware: HP Laptop with configurations; 4GBRAM, 500GBHarddisk and a 1.7GHZ Processor.
iii. Software include: ArcGIS 10.5, Erdas Imagine, Microsoft Excel 2016, Microsoft Excel 2016

The procedure for the investigation is shown in the flowchart presented in figure 2.

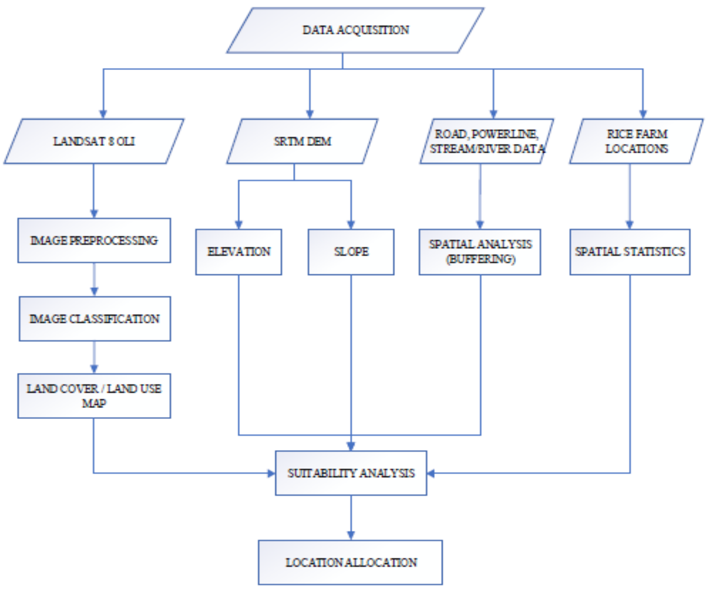

Fig. 2: work flowchart for location modelling

Table 1: Criteria (Factors/constraints) for Site Selection

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 atleast 1km from the rice farms.	Cost of rice transportation is dependent on the proximity of the rice farms to the aggregation center.	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 Powerlines	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	Factor	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

3. RESULTS AND DISCUSSION

The high suitable areas were extracted from the output raster and were converted to points to determine and select suitable point locations for the sitting of rice aggregation centres; this enabled the extraction of the coordinates of the sited aggregation centres (see Figure 3).

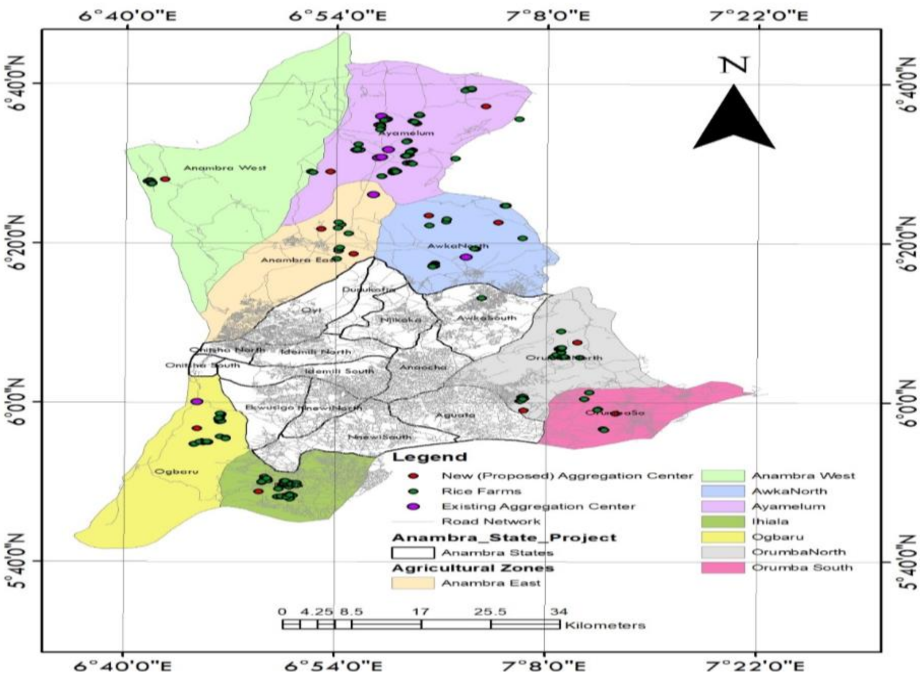

Figure 3: Suitability Map for Sited (Proposed) Aggregation Centres in Anambra State

From the suitability map in (Figure 3), and following ground truth carried out, it was important to note that formerly Ayamelum had 4 out of 7 of the total aggregation centres in Anambra state making it the zone with the highest concentration of aggregation centres to a total number of 163 rice farms. In Ayamelum, the aggregation centres 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 has 20 rice farms with no aggregation centre. 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. Ogbaru has one aggregation centre 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. Ihiala, Orumba North and Orumba South also had no aggregation centre to service a combined total of 92 rice farms. Anambra East has a total of 18 rice farms to one aggregation centre, 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. These are illustrated in Figures 4a and 4b.

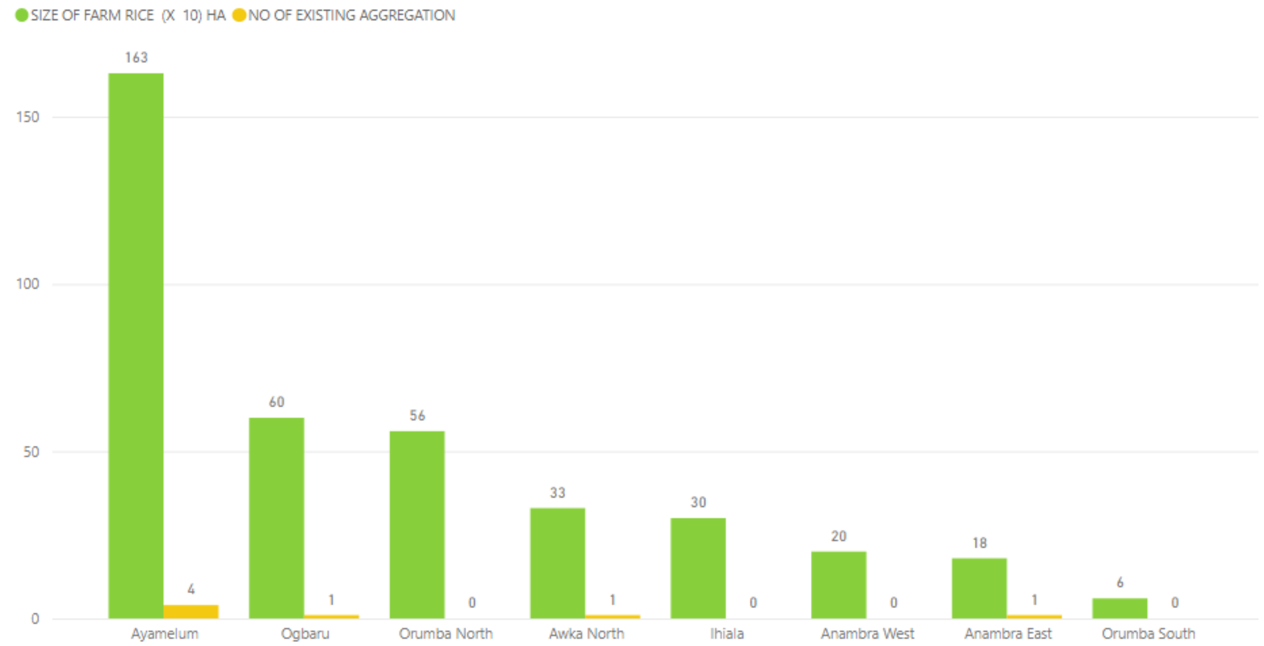

Figure 4a: Ratio of Existing Aggregation centres to Rice Farms in Anambra agricultural zone

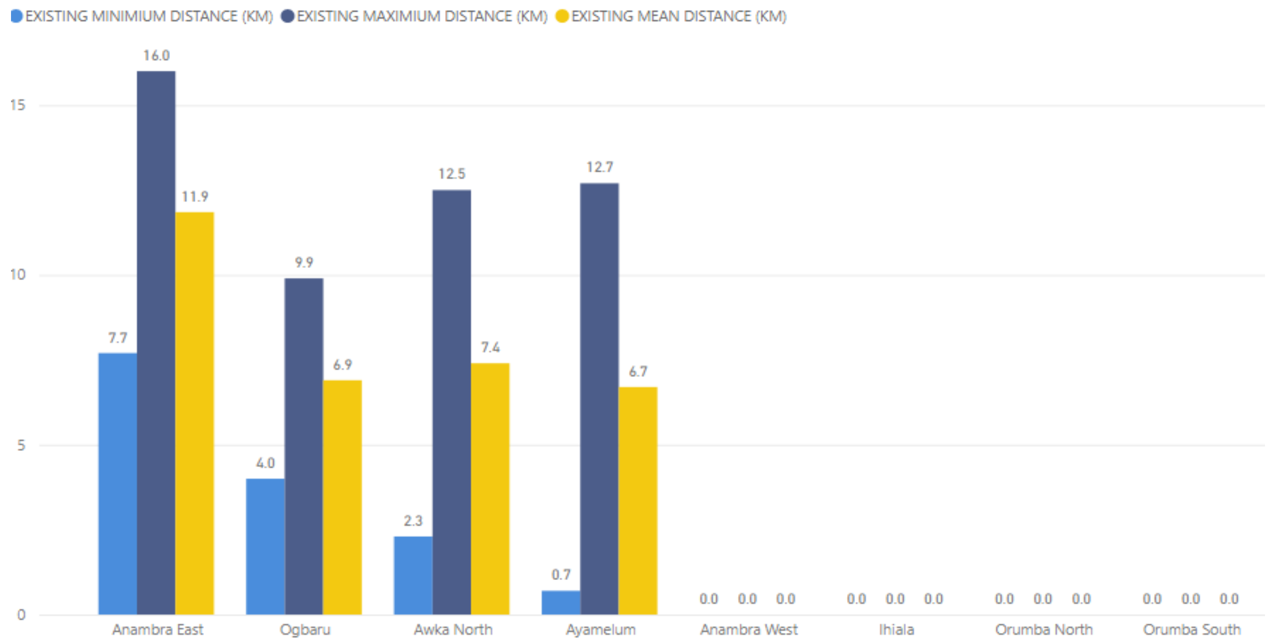

Figure 4b: The existing minimum, maximum and mean distance of Farms to Aggregation centres

Going by the results obtained from the analysis it is proposed that two locations be allotted to Ayamelum in addition to the existing centres, thereby bringing it to a total of 6 aggregation centres. The aggregation centres in Ayamelum- both the existing and the proposed locations, have a service zone with a minimum distance of 700m, maximum distance of 4.9km and a mean distance of 2.8km. Anambra East which also had one aggregation centre serving a total of 18 rice farms was allocated two aggregation centres that covers a minimum distance of 1.9km, maximum distance of 3.4km and a mean distance of 2.65km from the rice farms. Anambra West which previously had no aggregation centre was allocated one aggregation centre with a minimum distance of 1.7km, maximum distance of 2.4km and a mean distance of 2km. Awka North was also allocated two aggregation centres with a service area that covers a minimum distance of 2km, maximum distance of 4.6km and a mean distance of 3.3km from the rice farms. Orumba South which previously had no centre was proposed one aggregation site 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. Also, Orumba North which previously had no centre, was allocated two aggregation sites in a service area that covers a minimum distance of 2.3km, maximum distance of 4.6km and a mean distance of 3.4km from the rice farms. Ihiala, had no aggregation centre to serve a total of 30 rice farms but it was proposed that one (1) aggregation centre be allocated to the zone with 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 serving a total of 60 rice farms, but was allocated one (1) more aggregation centre with a minimum distance of 3.1km, maximum distance of 4.5km and a mean distance of 3.8km from the rice farms. These are illustrated in Figure 5a and 5b.

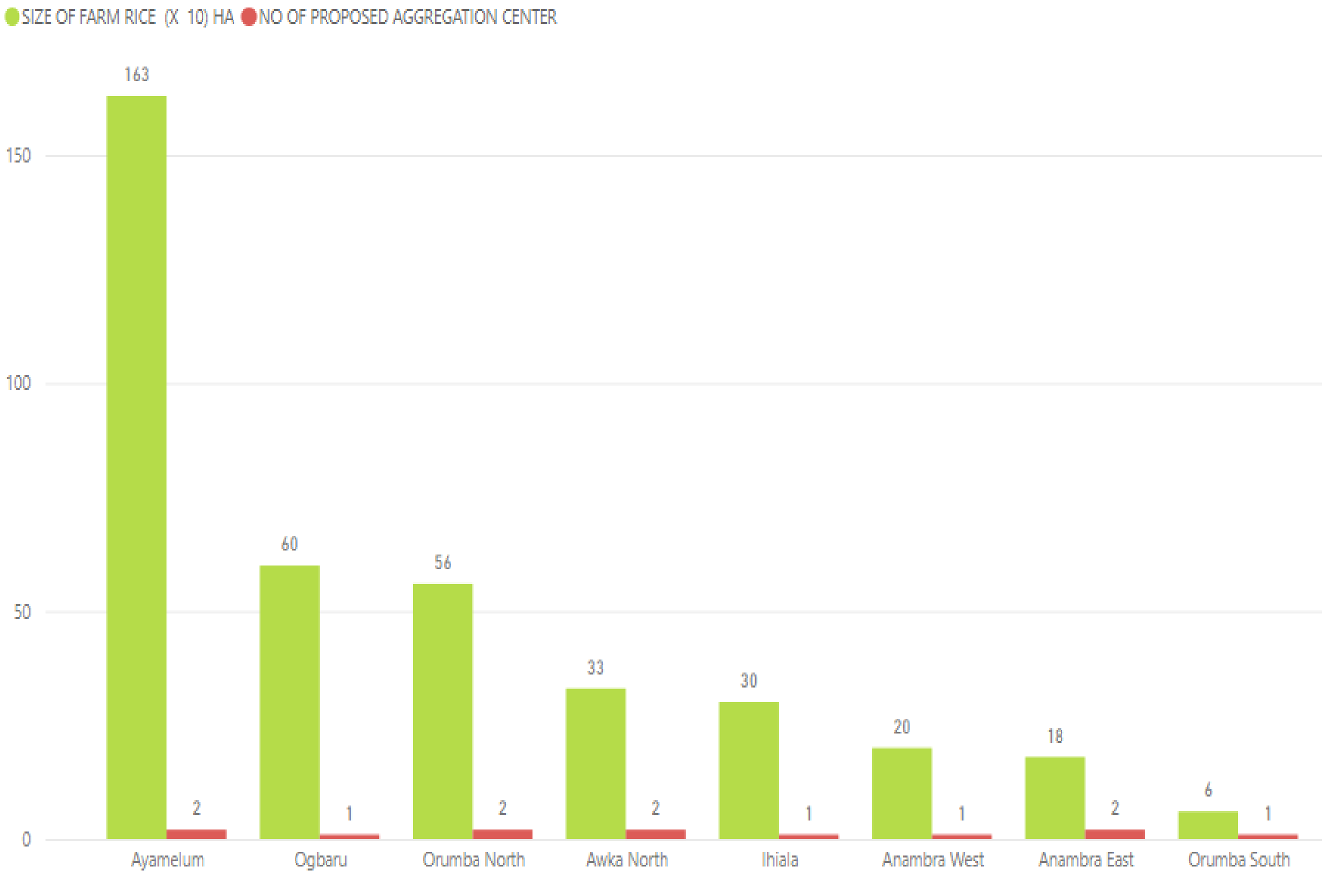

Figure 5a: Ratio of proposed Aggregation centres to Rice Farms in Anambra agricultural zone

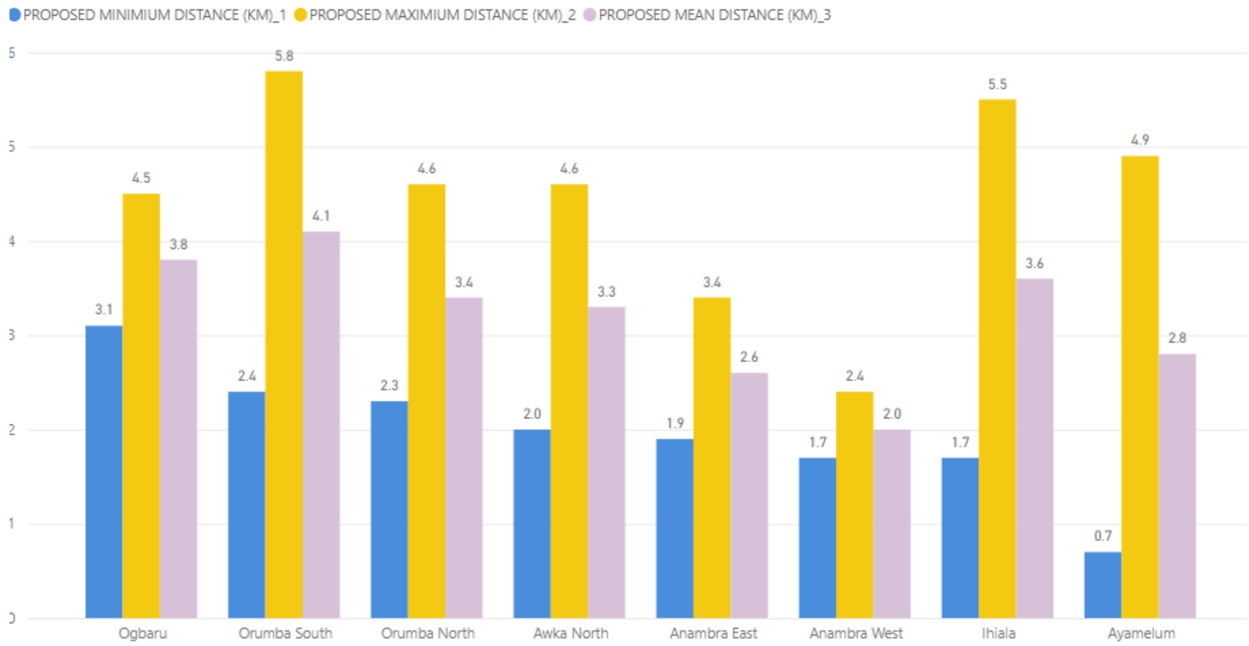

Figure 5b: Proposed minimum, maximum and mean distance of Farms to Aggregation centres

Also, comparing the mean distances from the rice farms to the existing aggregation centres 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 allocated centres optimized to realize the suitability of aggregation centres in proximity to the rice farms; this is shown in Figure 6.

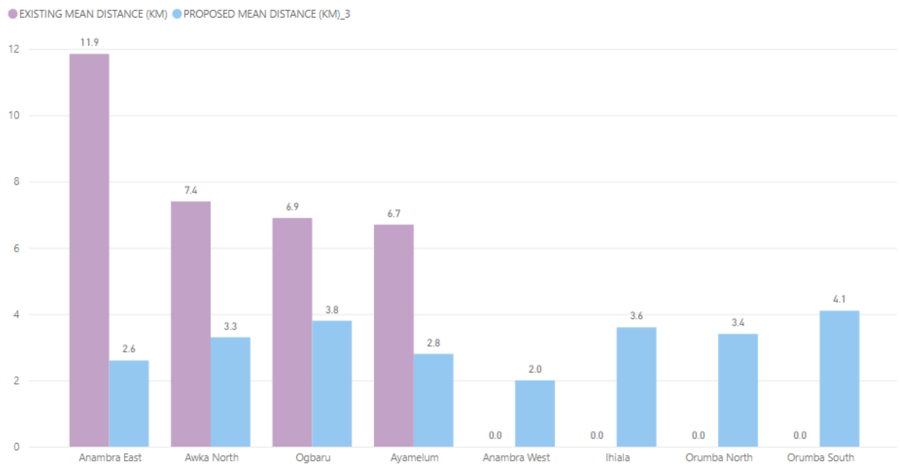

Figure 6: Mean distances from rice farms to existing and proposed aggregation centers

Having satisfied all the criteria by weighted linear combination, the potential locations for rice aggregation centres in the eight agricultural zones in Anambra state are at Nzam, ifite-ogwari, Onoia, Aguleri, Nando, Akenu, Achalla, Ezira, Ajali, Ndiokpalaeze, Ogbakuba and Uli, as shown in Figure 7 and Table 6.

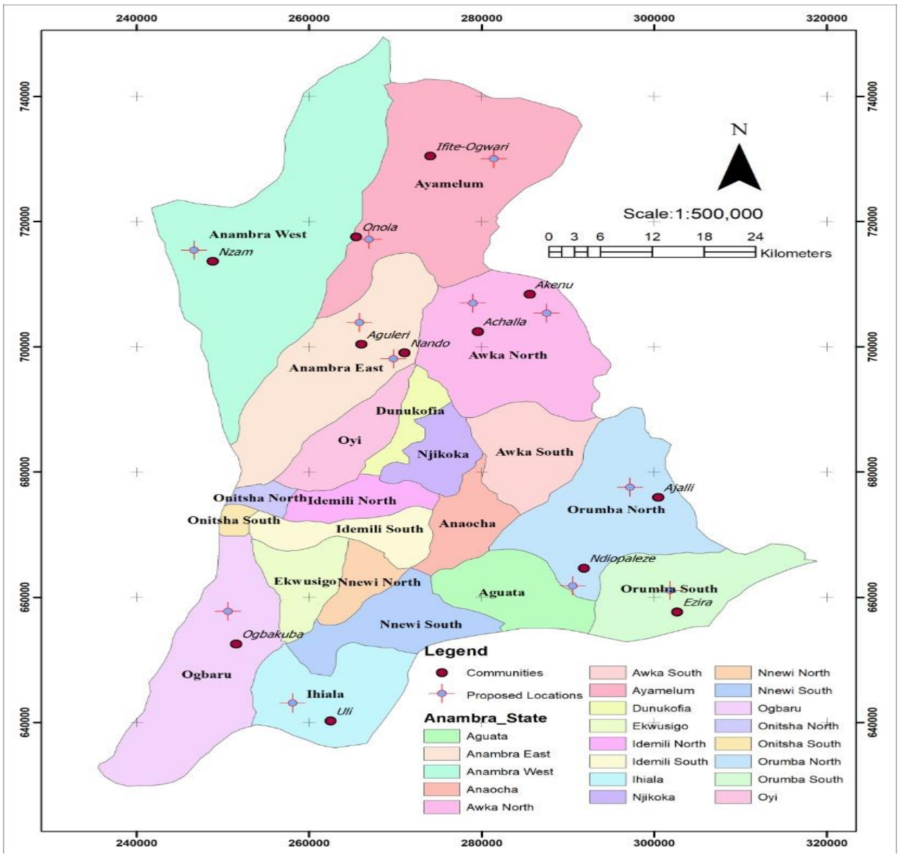

Figure 7: Map showing proposed locations for siting rice aggregation centres in agricultural zones

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

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

4. CONCLUSION

Location of Rice aggregation centre (RAC) can be achieved by spatial decision; spatial decisions mostly involve a large set of feasible alternatives. GIS has proven to be effective through the use of remotely sensed data in providing the required spectral and spatial information for generating information layers for rice aggregation site selection criteria. The GIS as a decision-making tool, being facilitated, merged various information layers as well as implementing the requisite analysis on the data. Although the GIS methodology makes the decision-making procedure more objective, there is still an element of subjectivity connected with the allocation of map weights and scaling. This also allows pliability to the planners to consider varying degree of importance to each criterion based on their experience. This study was able to apply spatial decision making in using the different criteria available to find out where rice aggregation centres can be situated within

Anambra State. The study discovered thirteen sites fulfilling all sitting criteria for where rice aggregation centres can be positioned with all sites exhibiting the best balance between all established criteria.

5. ACKNOWLEDGEMENTS

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6. COMPETING INTERESTS

Authors declare that there are no competing interests in existence in this research.

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