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Geospatial Mapping, Modelling and Optimization of Modular Rice Aggregation Centers in Anambra Zone

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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 and ensuring an 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 and a set 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 geospatial mapping, modelling and optimization of modular rice aggregation centers in Anambra zone. Geographical Information System (GIS) technology was used to model and optimized the modular rice aggregation location centers in Anambra zone. It revealed the optimal locations for siting a modular aggregation rice centerat Aguleri, Nando, Ifite-Ogwari, Onoia and Nzam all in Anambra zone. The goal throughout this study was to provide a reliable and complete analysis of siting of modular rice aggregation centers in the Anambra zone. Therefore the approach and results obtained in this study are recommended as a spatial decision making tool for site selection of modular rice aggregation rice centers in Nigeria and other countries.

Keywords: GIS; Geospatial Mapping; Modelling; Optimization; Anambra Zone; Rice aggregation center

1. Introduction

Nigerian agricultural sector is undergoing series of reformation that will help to bring about food security and stabilization in the country. The closure of border by Nigerian Government is a confirmation that aimed to spur farmers especially rice farmers to increase production and equally force the consumers to demand more domestic food products. Nigeria as a country is yet to attain self-sufficiency in rice production since demand is yet to equal supply (Nkwazema, 2016). Rice botanically known as Oriza sativa is a tropical crop cultivated in almost all partsof Nigeria including Anambra State. The indigenous ethnic groups in Anambra state comprises of 98% Igbo and 2% Igala mainly living in the Northwestern part of the state. Anambra East, West and Ayamelum (Anambra zone), Orumba North (Aguata zone), Awka North (Awka zone) and Ogbaru, Ihiala (Onitsha zone) play a host community to the production of rice and an aggregation centers where it can be stored for optimal value (FMARD, 2016).

Anambra State is situated between Latitudes 5°32' and 6°45' N and Longitude 6°43' and 7°22' E. The State has an estimated land area of 4,865sqkm^2 with a population of 4,177828 people as at the last census (NPC, 2006). The State equally have an annual temperature and rainfall of 25.9^{o}C and 138 mm respectively (Anambra Climate Summary, 2020). In Anambra Zone, many rice small growers are resource-poor and cultivate about 0.5 and 3 ha and their yield was 2.3/ha before the intervention of some projects like (FADAMA, FARMD and VCDP). The intervention of these projects, improved their yields to 4.5/ha due to the introduction of best agronomic practices. Rice is the main cereal crop, which is seriously affected by climatic factors (Abu et al., 2017) even in Anambra State. It is one of the fastest-growing food commodities in Nigeria with a likelihood of continued growth; its increase in demand is associated with the rapid population growth, urbanization and consumer's preference for rice as convenience food (Akande, 2003; Obianefo et al., 2020; USDA, 2014). Foyeku and Rice Millers (2019) reported that Nigeria annual rice demand in 2018 was 7 million metric tons while only 56% of this demand was produced in Nigeria. Equally, the annual rice demand growth rate in Nigeria is 7.8% and the supply growth rate is 5.5% which leaves a deficit demand-supply gap of 2.3%. Many researchers have reported that the problems hindering Nigeria from meeting local demand were low productivity, inefficiency in resource allocation, little or no access to improved varieties, and production in the hand of small scale out-growers who rely heavily on traditional technology (Oluwadamilola, 2018). Also, farmers are challenged by inadequate farm inputs like improved seeds, cost of agrochemicals, insufficient knowledge and information for best practices (Banful, 2011; Keelan et al., 2014). These farmers need to be abreast with the knowledge of efficiency in agricultural production especially in the area of resource allocation that will help to bring about increased agricultural productivity (Wategire and Ike, 2015). Corroboratively, researchers in Nigeria have argued that low productivity and high technical inefficiency are the major problems of rice production in Nigeria and Africa at large (Chaovanapoonphol et al., 2009). This suggests the need for farmers in Nigeria to be abreast with efficiency in resource allocation.

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. Already, there are five (5) existing aggregation centers in Anambra zone which does not service the location as required due to poor siting of the facilities. However, there are four (4) addition optimized aggregation centers to the locations which will aid to make the five (5) existing ones to be fully utilized. There by, making it nine (9) aggregation centers in total in Anambra Zone.

There is need for an efficient geospatial mapping and optimization 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 zone 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 mapping and optimization procedures, oriented towards service planning through the use of Geographical Information Systems (GIS) is a very important factor for proper sitting of aggregation centers in Anambra agricultural zones.

Geographic information systems (GIS) are 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 as tools for mapping and optimizing purposes; thus quite suitable for designing the location modelling process. According to Tali (2017), GIS location modelling helps engineers, planners and developers to locate facilities that will 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 (Rikalovic et al., 2014). Synergistic effect, generated by combining these tools contributes to the efficiency and quality of spatial analysis for industrial site selection (Khalid, 2013; Malczewski, 2006). One of the main 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 (Sarath et al., 2018; Fataei and Mohammadian, 2015). Therefore, the aim of this article is to study, map and optimize the best location for the rice aggregation centers in Anambra zone of the Anambra state.

2.0 Material 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 contain 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).Figure 1 and Figure 2 below shows; Map of Agricultural Zones in Anambra state and Map of the study area.

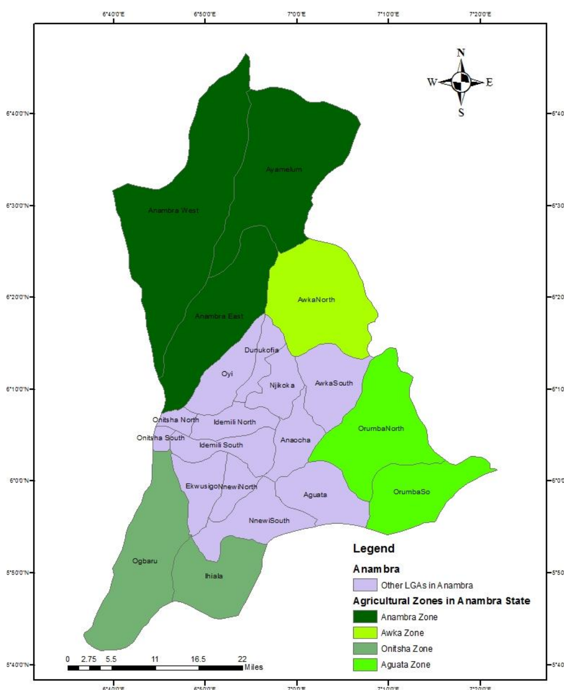

Figure 1: Map of Agricultural Zones in Anambra State

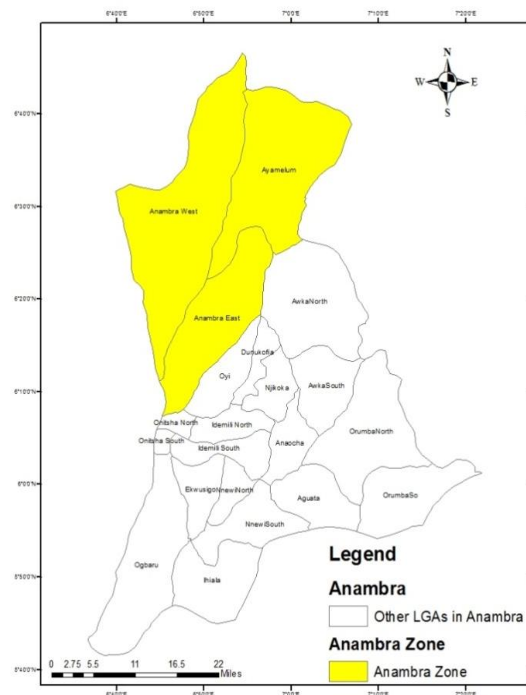

Figure 2: Map of the study area- Anambra Zone

The study area lies within the Anambra Basin and it is made up of Enugu Shale, Mamu Formation, AjaliSandstone, 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 (UN-HABITAT, 2009; Obianefo et al., 2020). 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 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 (UN-HABITAT, 2009; Obianefo et al., 2020). The natural vegetative covered are the existing agricultural zones which 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 the field of study; this includes GPS coordinates of Rice farms in Anambra state. Other data were obtained from Landsat 8 OLI image covering the study area and SRTM DEM of the study area (www.earthexplorer.usgs.gov, 2019). The Rivers, Power lines and Road shapefiles of the study area were obtained from the GIS lab Department of Surveying and Geoinformatics, Nnamdi Azikiwe University, Awka.

Table 1: coordinate of the participating local government area.

S/N	Local Government	Coordinate (UTM)
1.	Ayamelum	270111.2°E 722126.5°N- 279414.1°E 695114.1°N
2.	Anambra East	264572.9°E 717142.8°N - 264790.2°E 716986.0°N
3.	Anambra West	244559.4°E 714967.9°N- 245049.4°E 714432.5°N

Table 2 Sample representative of rice farmers in the 3 Local Governments

S/N	Local Government Area	No of Rice Farmers
1.	Ayamelum	2558
2.	Anambra East	436
3.	Anambra West	1027

Source: Anambra State Fadama database, (2018)

2.3 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 3.

Table 3: 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

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
λmax = 9.59
by substituting the values we have;
CI = 0.073
According to (Saaty, 1990) in Table 3; 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 which determine the selected 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.

3.0 Results and Discussions

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

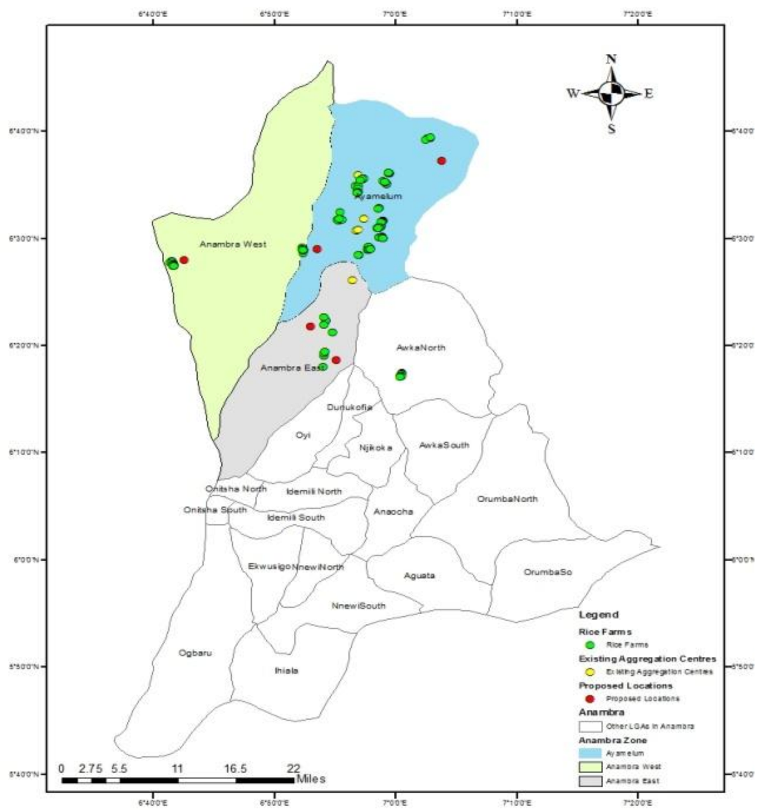

Figure 3: Located rice farms, existing and proposed aggregation centres in Anambra Zones.

From the suitability map (figure 3), 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. See figure 4.

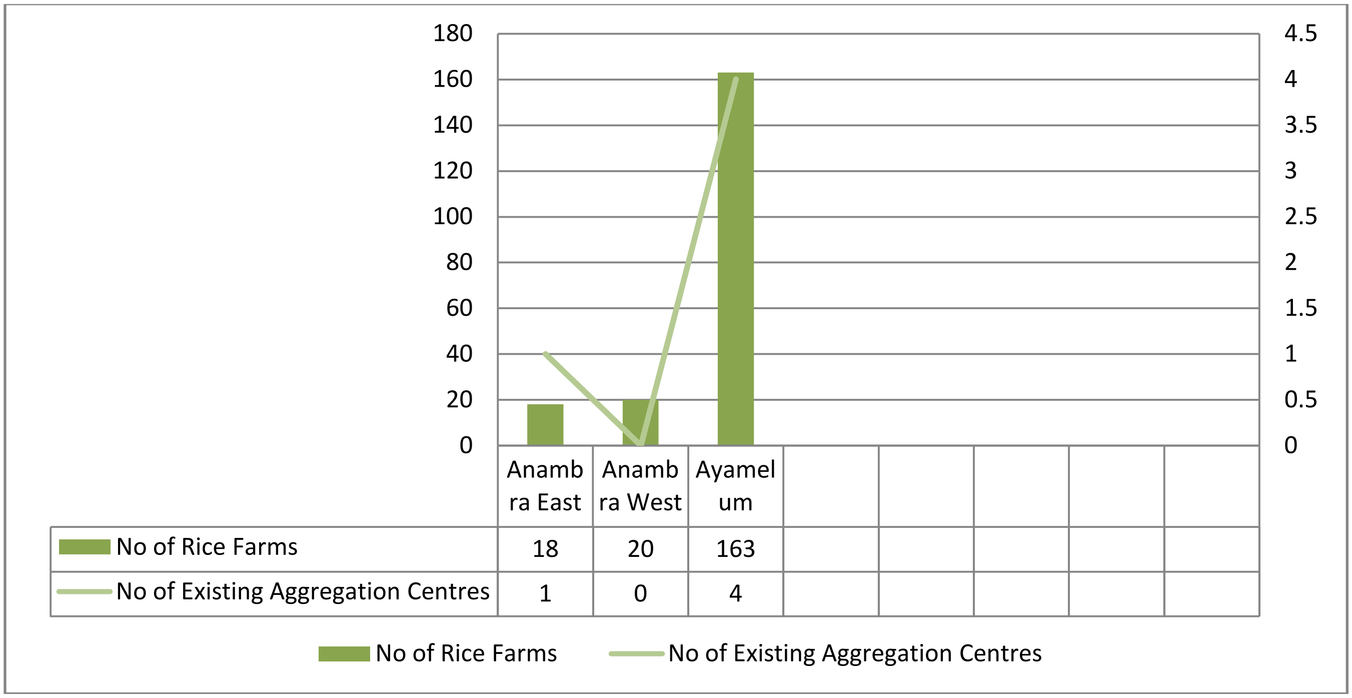

Figure 4: Ratio of Aggregation centers to Rice Farms in Anambra agricultural zone

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 cover a minimum distance of 1.9km, maximum distance of 3.4km and a mean distance of 2.65km from the rice farms, see figure 5.

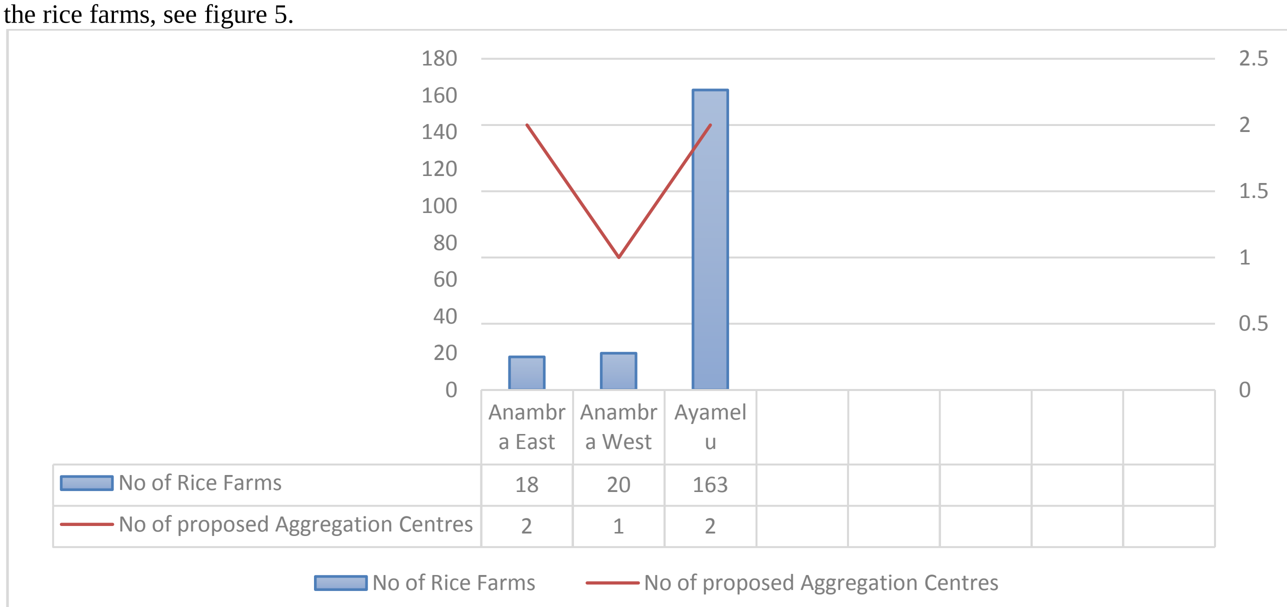

Figure 5: Ration of Proposed aggregation locations to rice farms in Anambra agricultural Zone

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, that the mean distances from the farms to the aggregation locations have been optimized from 6.7km to 2.8km. The mean distances from Anambra West which previously had no aggregation centers were also optimized to realize the suitable locations for aggregation centers in proximity to the rice farms, see figure 6.

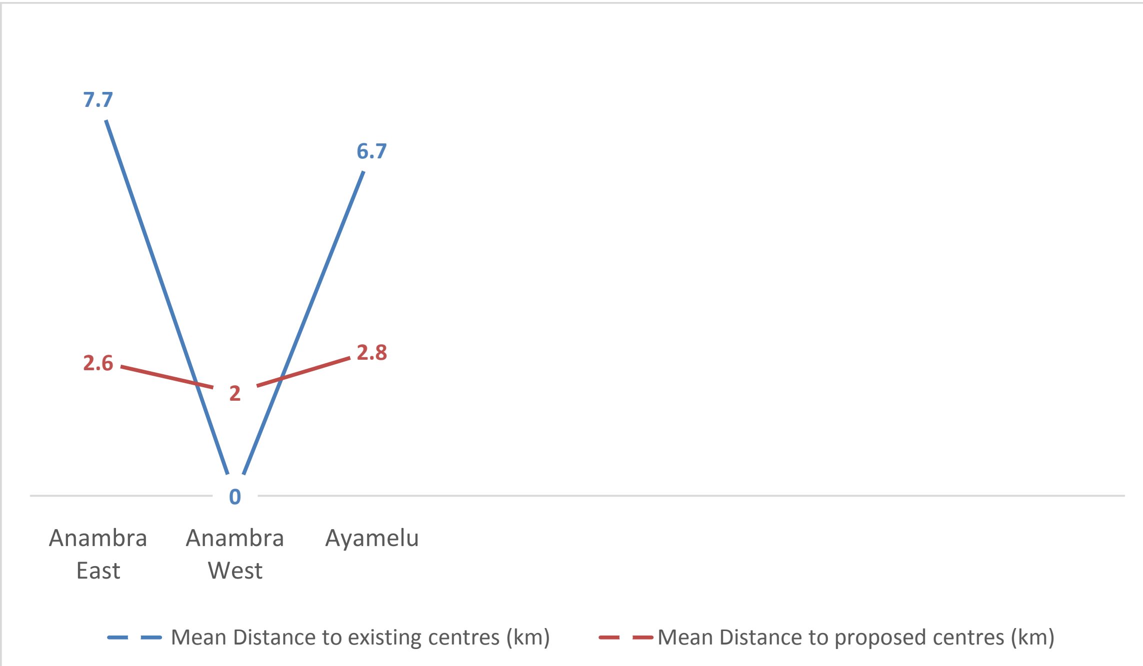

Figure 6: Mean distances from rice farms to existing and proposed aggregation centers.

Having satisfied all criteria by weighted linear combination, the potential locations for aggregation rice centers in the Anambra zones are located at Nzam, Onoia, Ifite-Ogwari, Aguleri and Nando. See table 4

Table 4: Proposed locations for sitting rice aggregation centers in Anambra 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	285982.481	732224.043	Ayamelum	IfiteOgwari

4.0. Conclusion

Modular rice aggregation center selection can be accomplished by studying, mapping, and optimizing by the spatially involving 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 for mapping and optimization. The GIS as a tool, being facilitated, combined various information layers as well as implementing the necessary analysis on the data, although the GIS methodology makes the studying, mapping and optimization more objective, there is still an element of subjectivity associated with the allocation of map weights and scaling. This also allows flexibility for the Engineers and Planners to incorporate varying degree of importance to each GIS-optimization base on their experience. This work were able to apply the studying, mapping and optimization of spatial base, using the different tools available to ascertain where modular rice aggregation centers can be located within Anambra Zone. The study located five sites satisfying all sitting conditions where modular rice aggregation centers can be sited with all sites exhibiting the best balance between all established conditions.

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