



Geographical Information System Based Multi-Criteria Analysis for Grain Storage Facility Siting in Jalingo Local Government Area, Taraba State, Nigeria

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ABSTRACT

Traditionally, grain storing facilities have been located without any spatial consideration within agrarian Local Government Areas (LGAs) like Jalingo LGA of Taraba State, Nigeria. This has contributed to loss of food security due to post harvest losses. The study developed a model called Multi-Criteria Decision Analysis (MCDA) using Geographic Information System (GIS) for the identification of optimum grain storage facility in Jalingo LGA. Six suitability criteria were tested on Landsat 9 OLI data, a 30 m SRTM Digital Elevation Model (DEM), and other ancillary vector data in ArcGIS Desktop 10.8. The suitability criteria were: land use/land cover, slope, distance to road, distance to river, distance to settlement, proximity to agricultural land. The Analytical Hierarchy Process (AHP) was employed to determine the weights of the criteria by means of a pairwise comparison. Distance to roads (27.4%) and agricultural land (34.9%) were the most important criteria. The consistency ratio of 0.036 suggested the weighting reliability was acceptable. The study area was classified as Suitable or Highly Suitable for grain storage development with the Weighted Sum Analysis, at about 84.7%. The three potential sites identified and ranked by area: Site A (1,468.80 ha), Site C (722.70 ha), and Site B (325.26 ha) were all within a north-western to central accessibility corridor. The results offer a replicable, evidence-based approach to assist in planning for grain storage and reducing postharvest losses in Jalingo LGA and other agro-ecological areas with similar characteristics.

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INTRODUCTION

Food security is a critical development issue in agrarian economies, since adequate, safe and nutritious food access is crucial for household welfare and economic growth. While expanding production is one important objective, post harvest losses can significantly cut down the amount of grain available to consumers. Losses can happen at various stages along the value chain, such as threshing, drying, transport, storage, processing and consumption, the latter of which is one of the important stages where losses occur. Traditional or improper storage methods may lead to 10-20% loss of grain in developing countries, while improved scientific storage methods can result in losses of 1-2% cereals (Kumar and Kalita 2017).

Lack of storage facilities, poor market access and poor logistics systems add to post harvest losses in sub-Saharan Africa. These limitations can lead to significant reductions in value of harvested cereal output and so reduce the rewards of greater cereal output, according to the World Bank report (2011). The location of storage structures is important in addition to the quality and management of the structures in which they are stored, as the structures need to be close to agricultural production areas, transportation networks, settlements, and drainage features, which can affect their accessibility, operational efficiency, and exposure to the environment. These are important challenges in Nigeria where cereals form a significant part of agricultural production and food supply. Barau et al. (2023) found that even in Nigeria, grain handlers are still using storage structures that may not be properly designed to consider the

favourable environmental and infrastructural conditions, thus putting stored grain at risk of moisture, mould growth and infestation by insects. Therefore, optimal spatial arrangement of the grain storage facilities is a crucial aspect of post harvest activity.

Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) are tools that can be used systematically to solve spatial facility-siting issues. The MCDA allows decision makers to compare alternatives according to a number of different criteria, some of which may be more important than others (Malczewski, 2006). Combined with GIS, the approach can be used to assess spatial alternatives, rank them based on geographic features and the priority given to each criterion. The Analytical Hierarchy Process (AHP) introduced by Saaty (1980) is a popular approach for determining the weights of the criterion and for checking the consistency of the judgments. A Consistency Ratio (CR) < 0.10 is acceptable.

The tools of GIS-MCDA have been used to address various spatial planning and infrastructure siting problems in Nigeria. Ajibade et al. (2020) used GIS-based MCDA in dam site selection in Imo State while Oluwanimifise and Anyaeche (2025) used GIS-MCDA in landfill site selection in Ibadan. The applications below illustrate the value of combining several spatial factors for infrastructure-siting decisions. The application of proximity-based criteria is also in line with Tobler's (1970) First Law of Geography, which states that 'everything is related to everything else, but near things are more related to each other than distant'. The principle can be

applied to the spatial arrangement of potential storage areas, and aspects like agricultural land and transport infrastructure. Although GIS-MCDA has been applied to siting infrastructure issues, its application to grain-storage facility location is still limited, especially in north-eastern Nigeria. In a systematic review of GIS applications in agriculture, Mathenge et al. (2022) discovered that most of the research has focused on production-related applications such as crop yield, soil fertility, drought and other agricultural management issues, and that sub-Saharan Africa was somewhat under-represented in the literature reviewed. This suggests that a spatial approach for making decisions about postharvest and agricultural infrastructure using GIS can be expanded. The administrative and commercial hub of Taraba State is Jalingo Local Government Area, which is mainly agrarian in nature and is a key grain collection and distribution point from the surrounding farming communities. The spatial planning of grain-storage locations in the LGA has not been systematically assessed based on an integrated spatial assessment of biophysical and infrastructural criteria. Filling this gap can enable decision makers to have access to spatial information to enhance the planning and future development of grain-storage infrastructure.

This study has, therefore, used GIS-based MCDA model in identifying optimal locations for grain-storage facilities in Jalingo LGA, Taraba State by combining Earth Observation-derived datasets with GIS and AHP. The specific objectives were to: (i) evaluate spatial distribution of six selected site suitability criteria; (ii) calculate weights of the site suitability criteria through AHP; (iii) combine the site suitability criteria and create a grain storage suitability map using GIS-based weighted analysis; and (iv) evaluate and propose possible locations for grain storage facilities.

The conventional approach to locating grain storage facilities in agrarian Local Government Areas (LGAs) like Jalingo LGA, Taraba State of Nigeria has not been done systematically. This has been responsible for post harvest losses and food insecurity. The study developed a Geographic Information System (GIS) based Multi-Criteria Decision Analysis (MCDA) model for determining the most suitable grain storage locations in Jalingo LGA. Landsat 9 OLI-2 images, 30 m SRTM DEM and ancillary vector data were analyzed in ArcGIS Desktop 10.8, according to six suitability criteria: land use/land cover, slope, distance to roads, distance to rivers, distance to settlements, and proximity to agricultural land. AHP has been adopted to weight the criteria by pairwise comparison. Distance to roads was the second most important

criterion (27.4%), followed by agricultural land (34.9%). The consistency ratio was 0.036, which is considered a good reliability of weights. The Weighted Sum Analysis indicated that about 84.7% of the study area belonged to Suitable or Highly Suitable grain storage development category. Three possible sites in the HS class were identified and ranked by area (Site A 1468.80 ha, Site C 722.70 ha, and Site B 325.26 ha) all within a North-Western to Central accessibility corridor. The results give a replicable and evidence based model to be used for grain storage planning and minimizing post harvest losses in Jalingo LGA and other agro-ecological zones of similar nature.

MATERIALS AND METHODS

Study Area

Jalingo LGA is one of sixteen Local Government Areas in Taraba State, north-eastern Nigeria, and is the state capital. It is roughly located within the latitude range of 8°47'N to 8°56'N and longitude range of 11°09'E to 11°30'E with an official administrative area of approximately 195 km² (see Figure 1) bordered by Ardo Kola LGA to the north and east, Lau LGA to the west and Yororo LGA to the south. The LGA is tropical wet-and-dry with two different seasons; rainy season (April to October) and dry season (November to March). The mean annual rainfall is 900-1,300 mm with maize, rice, sorghum and millet grown under rain-fed conditions and the mean annual temperatures are 26-32°C.

The relief is typically represented by gently rolling plains interspersed with isolated hills, varying in elevation from around 175 m to 792 m above mean sea level (AMSL), as determined from the SRTM DEM. It has a predominantly dendritic drainage pattern with the Lamurde river and its tributaries draining the LGA in the larger Benue River Basin. The geology consists of crystalline Basement Complex rocks (granites, migmatites, gneisses and schists) and younger alluvial rocks along river floodplains. The natural vegetation is in the Northern Guinea Savannah zone but has been greatly modified with extensive cultivation, urban expansion and grazing. The population of the LGA, according to the National Population Census in 2006, is about 140,000 persons, which has since increased greatly as a result of urbanisation and being the capital of the state. The main livelihood of the rural population is agriculture while Jalingo metropolis is the main commercial centre to collect, store and distribute agricultural produce from surrounding rural communities.



Figure 1: Location Map of Jalingo LGA, Taraba State, Nigeria

Data Sources

The Landsat 9 Operational Land Imager-2 (OLI-2) images (2024) and the Digital Elevation Model (DEM) Shuttle Radar Topography Mission (SRTM) 30 m were downloaded from the United States Geological Survey (USGS) EarthExplorer platform. The information for the road and river network was

accessed from OpenStreetMap and for the administrative boundary an official GIS database was used. The classified land use/land cover map was used as the basis for creating settlement and agricultural land layers. All data were mapped within ArcGIS Desktop 10.8 in UTM WGS 1984 Zone 32N.

Table 1: Spatial Datasets Used

Dataset	Description	Source	Resolution
Landsat 9 OLI-2 (2024)	LULC mapping	USGS EarthExplorer	30 m
SRTM DEM	Elevation/slope	USGS EarthExplorer	30 m
Administrative boundary	LGA boundary	Official state GIS database	—
Road/river network	Accessibility/drainage	OpenStreetMap	—
Settlements, agricultural land	Proximity criteria	Derived from LULC	30 m

Image Pre-processing and Classification

Before supervised classification, Landsat 9 OLI-2 data was pre-processed in a series of steps that included performing layer stacking (combination of the visible, near-infrared and shortwave infrared bands into a composite image), clipping to the LGA boundary using the Extract by Mask tool, projecting to WGS 1984 UTM Zone 32N, and performing image enhancement (contrast stretching and false-colour compositing) to discriminate land cover features before supervised classification.

Land use/land cover (LULC) was classified using Maximum Likelihood Classification (MLC) algorithm in ArcGIS Desktop 10.8. Based on this assumption, MLC classifies each pixel to the class having the greatest probability of occurrence, and has been widely used in LULC applications due to its performance in separating spectrally similar LC types. Fifty training samples were collected from fifty visual interpretation of the Landsat imagery using Google Earth Pro for each of five classes (Agricultural Land, Built-up Area, Vegetation, Water Body, and Bare Land). Classification results were not quantitatively assessed using a confusion matrix, an overall accuracy, and a Kappa coefficient, but rather visually, by comparing the classification with the original imagery and imagery from the Google Earth Pro, which is acknowledged as a limitation of the present study (see Section 4.0).

Suitability Criteria and Reclassification

The suitability of potential storage sites for grain storage facilities was evaluated using six criteria derived from literature review and the physical and infrastructural attributes of the study area, and the needs of grain storage operations –

land use/land cover, slope, distance from roads, distance from rivers, distance from settlements and proximity to agricultural land. The Slope tool in ArcGIS Desktop 10.8 was used to calculate slope from the SRTM DEM. The road, river, settlement and agricultural land vector layers were converted to continuous proximity (distance) surfaces using Euclidean Distance analysis, which was considered to be a better proxy for suitability of a location for grain storage, than an intrinsic property of the location itself.

The objective was to minimize transportation distance between production areas and storage facilities; therefore, the suitability of the land use/land cover was determined, with agricultural land being considered as most suitable and water bodies and vegetation as environmentally sensitive and being considered as less suitable. Slope indicates construction feasibility and drainage lesser the slope lesser will be the earthwork, drainage, and erosion related risk. Road access is measured by distance to roads and is an important factor in determining operating cost and market linkages. The distance from rivers will also influence flood hazard, as areas that are near drainage channels will not be as good because of the possibility of moisture and damage to structures. Distance to settlements was considered to be an optimum range indicator, as a compromise of labour and market access to the avoidance of land-use conflict in highly developed settings. The prime objective of minimising transport distance and post harvest handling time between farm and store is realised by being in close proximity to agricultural land.

The Reclassify tool was used to reclassify each criterion on a common suitability scale of 1-5 (1 = least suitable, 5 = most suitable). Table 2 summarises the reclassification scheme.

Table 2: Reclassification Scheme for Suitability Criteria (1–5 Scale)

Criterion	Class Ranges (Score 5 → 1)	Notes
Distance to Roads (m)	0–1,000 / 1,000–2,500 / 2,500–5,000 / 5,000–8,000 / 8,000–10,869	Closer = more suitable
Distance to Rivers (m)	3,000–11,675 / 1,000–3,000 / 500–1,000 / 250–500 / 0–250	Farther = more suitable (flood risk)
Proximity to Agric. Land (m)	0–400 / 400–800 / 800–1,200 / 1,200–1,600 / 1,600–1,995	Closer = more suitable
Distance to Settlements (m)	300–700 (=5) / 700–1,200 / 1,200–1,800 / 0–300 (=2) / 1,800–2,275 (=1)	Optimal-range (non-monotonic)
Slope (°)	0–3 / 3–8 / 8–15 / 15–25 / 25–62	Gentler = more suitable
LULC	Agricultural (5) / Vegetation (4) / Built-up (3) / Bare Land (2) / Water Body (1)	Class-based scoring

AHP Weighting and Weighted Sum Overlay

The six criteria were compared against one another using pairwise comparison, with each criterion receiving a value on Saaty's fundamental 9-point scale, ranging from 1 (equal importance) to 9 (extreme importance) and the reciprocal

value where the criterion was deemed less important than the other. The judgments that underpinned Table 3 were based on the operational requirements of the grain storage facilities, with the key considerations being ease of access to the agricultural production areas and ease of access to

transportation networks, but with environmental factors like flooding and inappropriate terrain minimised.

The pairwise comparison matrix was normalised column-wise, and then the normalised matrix was solved for the principal eigenvector to obtain the relative importance of each criterion (called the criterion weights). The method was used instead of a naive approximation of a column-average due to the fact that it gives the mathematically correct solution as per the original formulation of Saaty (1980) and is directly related

to the calculation of the Consistency Ratio. Internal consistency of the judgements between pairs of criteria was assessed using the Consistency Index ($CI = (\lambda_{max} - n)/(n - 1)$), λ_{max} = the principal eigenvalue, n = the number of criteria) and the Consistency Ratio ($CR = CI/RI$, where RI = the Random Index corresponding to the number of criteria, $RI = 1.24$ for $n = 6$). A CR less than 0.10 is considered acceptable judgement consistency level (Saaty, 1980).

Table 3: AHP Pairwise Comparison Matrix

Criteria	LULC	Slope	Roads	Rivers	Settl.	Agric.
LULC	1	3	½	3	4	1/2
Slope	1/3	1	¼	2	3	1/5
Roads	2	4	1	5	5	1/2
Rivers	1/3	½	1/5	1	2	1/4
Settlements	¼	1/3	1/5	1/2	1	1/5
Agric. Land	2	5	2	4	5	1

Table 4: Final Criterion Weights and Consistency Results

Criterion	Weight	Rank
Agricultural Land	0.349	1
Distance to Roads	0.274	2
Land Use/Land Cover	0.181	3
Slope	0.088	4
Distance to Rivers	0.064	5
Distance to Settlements	0.044	6
$\lambda_{max} = 6.225$; $CI = 0.045$; $RI = 1.24$; $CR = 0.036$ (acceptable, < 0.10)		

The Weighted Criteria were combined using the Weighted Sum Overlay technique in the ArcGIS Desktop 10.8 software, based on the following equation:

$$SI = (0.181 \times LULC) + (0.088 \times Slope) + (0.274 \times Roads) + (0.064 \times Rivers) + (0.044 \times Settlements) + (0.349 \times Agricultural\ Land)$$

The resulting suitability index (SI) raster was classified into five suitability classes (Unsuitable, Low Suitable, Moderate Suitable, Suitable and Highly Suitable), and candidate sites were selected from the Highly Suitable class and ranked by area, considering contiguous area, accessibility and proximity to agricultural land.

RESULTS AND DISCUSSION

Land Use/Land Cover

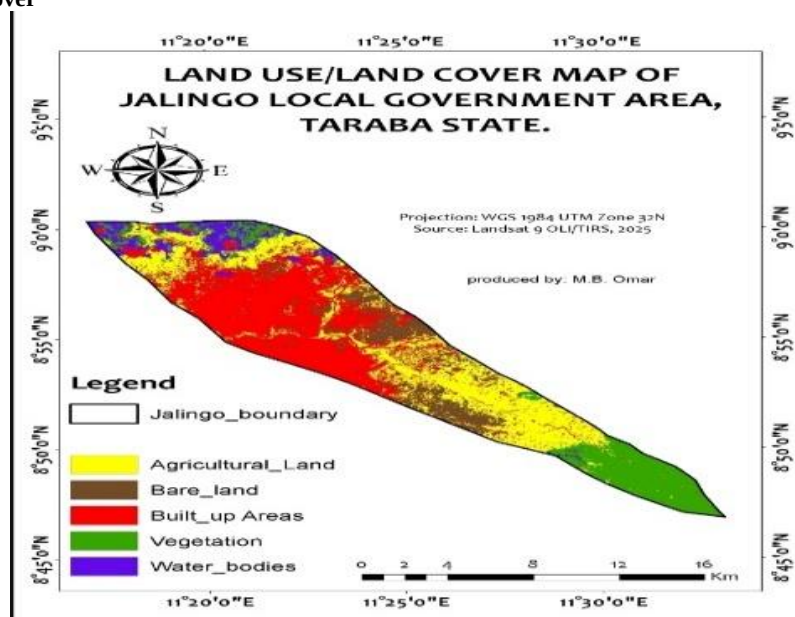


Figure 2: Land Use/Land Cover Map of Jalingo LGA

Table 5: Area Distribution of Land Use/Land Cover Classes

LULC Class	Area (km ²)	Percentage (%)
Built-up Areas	71.37	37
Agricultural Land	55.78	29
Vegetation	29.45	15
Bare Land	22.83	12
Water Bodies	11.11	6
Total	190.55	100

Built-up Areas (37%) and Agricultural Land (29%) were the predominant classes and together occupied 66% of the LGA, reflecting Jalingo's dual role as an urbanizing state capital and an agrarian hinterland. This agrees with Mathenge et al. **Terrain and Reclassified Suitability Criteria**

(2022), who state that in the agrarian LGAs of Nigeria, agricultural and built-up areas are the usual dominant ones in rapidly urbanising LGAs.

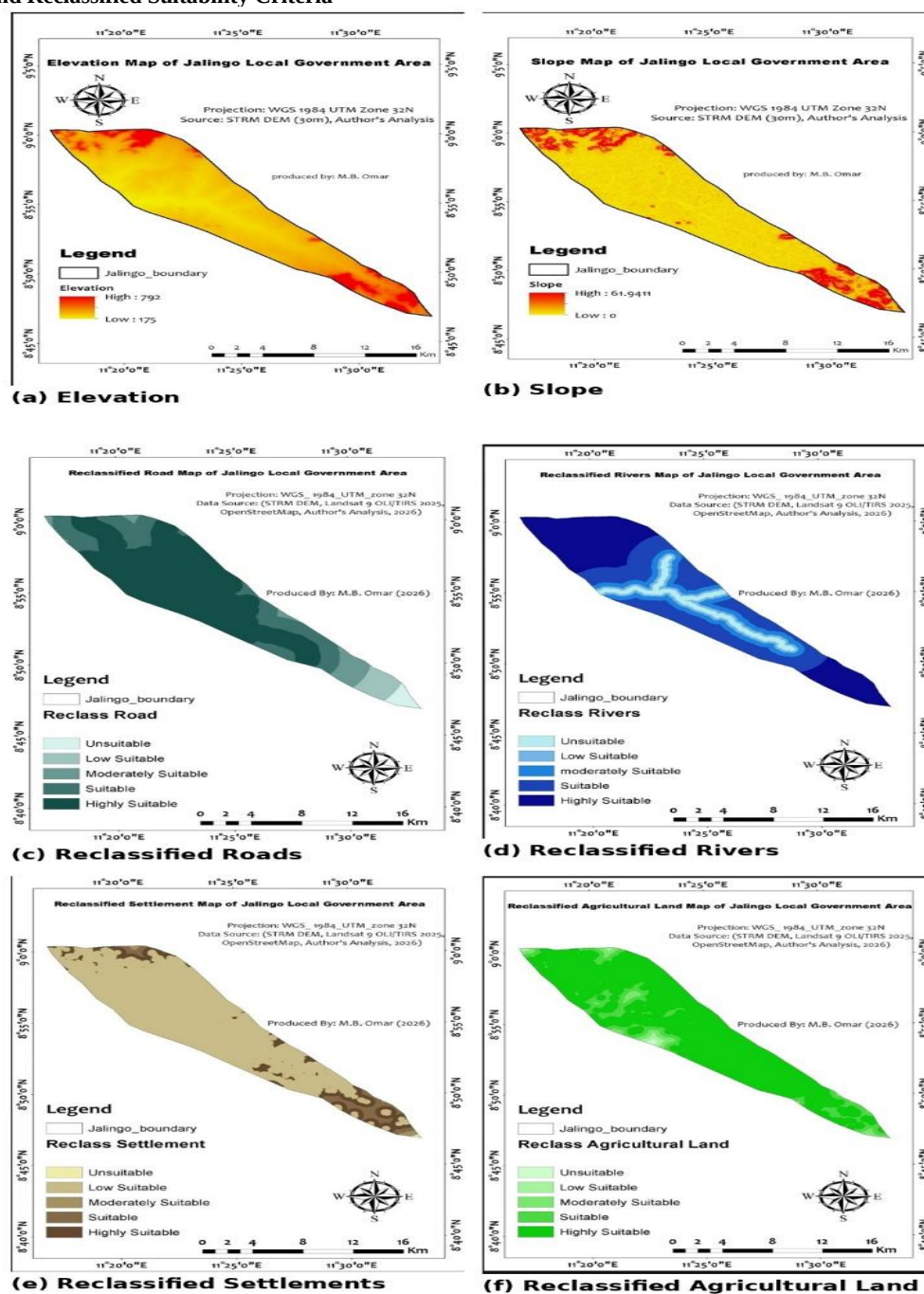


Figure 3: Derived and Reclassified Suitability Criteria — (a) Elevation, (b) Slope, (c) Reclassified Roads, (d) Reclassified Rivers, (e) Reclassified Settlements, (f) Reclassified Agricultural Land

Elevation ranged from 175 to 792 m with the slope ranging from 0° to about 61.94° (Figures 3a-b). The majority of the slope gradient in the LGA was gentle (0 to 8°), with steep slopes confined to the northern and southern margins (and not the main grain storage areas) and so not likely to prevent the uptake of large tracts of suitable land from being considered for grain storage siting.

Strong spatial differentiation was observed for road accessibility (Figure 3c): suitability was high in the central and northern corridor of the LGA, which has a dense road network, and reduced towards the south-eastern end of the LGA, where roads are less connected. This significant spatial contrast will have a high spatial weighting (AHP 27.4%, Table 4), and thus have significant impact on the final suitability result. The influence of the suitability surface of the

river proximity criterion is expected to be comparatively small since, although it has a clear spatial pattern, it was given the lowest AHP weight (6.4%).

Settlement suitability (Figure 3e) was not monotonic, but rather had an optimal range, showing moderate suitability at 300-700 m from settlement cluster patches, but not necessarily close to them, as there was a trade-off between accessibility to labour/market and land-use conflict risk. The agricultural land proximity (Figure 3f) was also near ubiquitous across the LGA, with a uniform favourability grade across the LGA and the narrow 0-400 m distance threshold, suggesting that agricultural land had the highest positive influence on the final suitability map, that roads and rivers would have the greater share of spatial differentiation among candidate locations.

Grain Storage Suitability Map

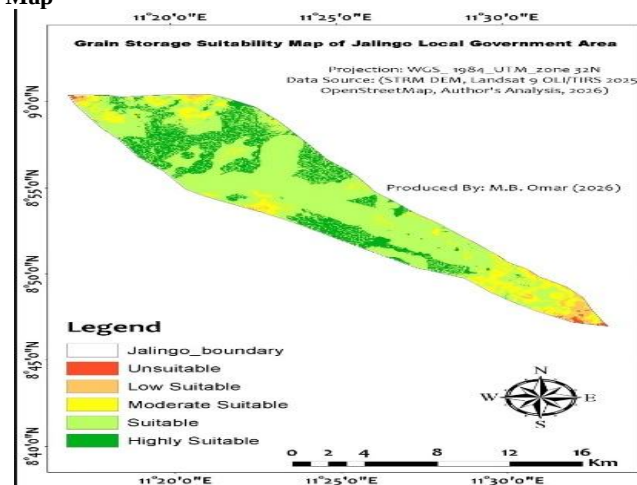


Figure 4: Grain Storage Suitability Map of Jalingo LGA

Table 6: Area Distribution of Suitability Classes

Suitability Class	Area (km ²)	Percentage (%)
Unsuitable	0.58	0.31
Low Suitable	4.15	2.20
Moderate Suitable	23.98	12.75
Suitable	119.98	63.79
Highly Suitable	39.38	20.95
Total classified area	188.07	100.00

The generally favourable weight and scoring of the agricultural land criterion, with about 84.7% of the classified area scoring Suitable or Highly Suitable for grain storage siting, suggests favourable conditions were generally present

throughout the LGA. This pattern is explained in more detail in this respect with similar GIS-MCDA facility-siting studies, as mentioned in Section 3.5.

Candidate Site Selection

Table 7: Ranked Candidate Sites for Grain Storage Facility Development

Site	Area (ha)	Easting (m)	Northing (m)	Class	Rank
Site A	1,468.80	757,753.91	991,142.11	Highly Suitable	1
Site C	722.70	766,498.52	981,435.88	Highly Suitable	2
Site B	325.26	764,764.65	988,476.67	Highly Suitable	3

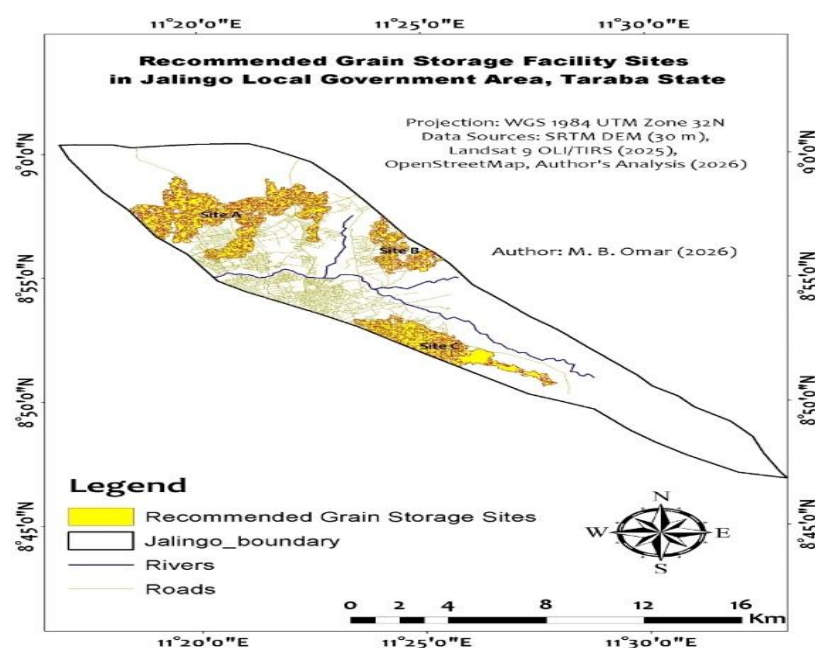


Figure 5: Recommended Grain Storage Facility Sites in Jalingo LGA

Within the Highly Suitable class, three candidate sites were identified all located within a single accessibility corridor in the north-western to central part of the LGA, with the two most weighted criteria, road accessibility and agricultural proximity, having a combined weight of 62.3%. The largest (1,468.80 ha) and top-ranked site (A) has the most potential for phased development. Instead of being evenly spread throughout the LGA, it is a spatial clustering, which is consistent with the pattern reported in the GIS-MCDA dam-site selection by Ajibade et al. (2020) who found that distribution of the most heavily weighted criteria was a key determinant in the location of candidate sites, and which also suggests a planning trade-off between locating development based on suitability score alone and spreading it across a wider geographic area in the LGA's more peripheral zones.

Discussion

The spatial distribution of land use/land cover (LULC) provides an important basis for understanding the feasibility of grain storage facility development in Jalingo Local Government Area (LGA). Built-up areas constituted the largest LULC class (37%), followed by agricultural land (29%), vegetation (15%), bare land (12%), and water bodies (6%). The relatively large proportion of agricultural land reflects the agrarian character of the LGA, while the substantial extent of built-up areas indicates the influence of urban development around Jalingo metropolis. From a grain-storage perspective, the extensive agricultural land provides an important spatial advantage because storage facilities located relatively close to production areas can potentially reduce the distance and time involved in transporting harvested grain.

Terrain characteristics also influenced the spatial suitability of the study area. Elevation ranged from approximately 175 to 792 m above mean sea level, while slope ranged from 0° to 61.94°. Most of the LGA was characterised by gentle slopes of 0–8°, whereas steeper terrain occurred mainly along the northern and southern margins. The predominance of gentle terrain is favourable for storage-facility development because flatter locations generally require less earthwork and are easier to develop than steep locations. However, slope cannot be considered independently of drainage and flood-related

conditions. This provides justification for incorporating both slope and distance from rivers into the suitability model.

Road accessibility emerged as the second most influential criterion, receiving an AHP weight of 27.4%. The road-suitability analysis showed greater suitability in the central and northern parts of the LGA, while suitability decreased towards the south-eastern part. The importance assigned to road accessibility reflects the role of transportation and logistics in agricultural supply chains. The World Bank (2011) identified weaknesses in storage infrastructure, market access and logistics as factors contributing to postharvest losses in sub-Saharan Africa. Therefore, locating storage facilities in areas with favourable road access can facilitate the movement of harvested grain between farms, storage facilities and markets and may reduce transportation-related constraints.

Distance from rivers received an AHP weight of 6.4%, making it the fifth-ranked criterion. Although this weight was relatively low compared with agricultural land and road accessibility, river proximity remains relevant because locations close to drainage channels may be exposed to flooding, excessive moisture and potential damage to storage infrastructure. The suitability analysis therefore favoured locations farther from rivers. This criterion complements the slope analysis because an appropriate storage location should have favourable terrain while also minimising exposure to environmental conditions that could compromise the safety and durability of storage infrastructure.

Distance from settlements received the lowest AHP weight of 4.4%. Unlike road accessibility and agricultural proximity, settlement distance was treated as an optimal-range criterion rather than assuming that greater distance always produces greater suitability. Locations between 300 and 700 m from settlements received the highest suitability score. This range provides a balance between accessibility to labour, services and markets and the avoidance of potential land-use conflicts associated with locating large storage facilities immediately within densely built-up areas. This criterion is particularly relevant to Jalingo LGA because built-up areas constituted 37% of the study area.

Agricultural land received the highest AHP weight (34.9%), demonstrating that proximity to agricultural production areas

was considered the most important factor in determining suitable locations for grain storage facilities. This reflects the primary role of storage within the agricultural supply chain, where reducing the distance between production areas and storage facilities can facilitate the collection and handling of harvested grain. The relatively widespread distribution of agricultural land in the LGA also contributed to its strong influence on the final suitability surface. Importantly, agricultural land and road accessibility together accounted for 62.3% of the total AHP weight, indicating that proximity to production areas and transportation networks largely influenced the spatial pattern of the final suitability map.

The AHP consistency ratio of 0.036 was below the commonly accepted threshold of 0.10 proposed by Saaty (1980), indicating an acceptable level of consistency among the pairwise comparisons. Agricultural land, road accessibility and LULC were ranked first, second and third, respectively, while settlement distance received the lowest weight. The weighting pattern demonstrates that the model prioritised direct access to agricultural production and transportation infrastructure while also incorporating physical and environmental constraints. Similar applications of GIS-MCDA have demonstrated the usefulness of combining multiple spatial criteria to support facility-siting decisions in Nigeria, including dam-site selection by Ajibade et al. (2020) and landfill-site selection by Oluwanimifise and Anyaechie (2025).

The final suitability analysis showed that approximately 84.7% of the study area fell within the Suitable or Highly Suitable categories, comprising 63.79% Suitable and 20.95% Highly Suitable areas. The relatively large proportion of suitable land can be attributed partly to the prevalence of favourable conditions associated with agricultural proximity and road accessibility. However, the finding does not imply that all areas classified as Suitable or Highly Suitable are equally appropriate for immediate construction. Rather, the suitability map provides a spatial screening framework for identifying areas that warrant more detailed investigation. The proportion of land classified as suitable is also dependent on the criteria, suitability thresholds and weights applied in the model. Consequently, the 84.7% figure should be interpreted within the methodological context of the present study rather than as an inherent characteristic of GIS-MCDA. The three identified candidate sites in the Highly Suitable class were ranked based on area and spatial suitability. The number of hectares for the candidate areas were ordered as follows: Site A (1,468.80 ha), followed by Site C (722.70 ha) and Site B (325.26 ha). The three sites were in a north-western to central accessibility corridor. Their spatial concentration is similar to what has been observed for the strong interaction of agricultural proximity and road accessibility (62.3% of the total criterion weight). Also, Ajibade et al. (2020) showed that the spatial distribution of multiple weighted criteria can affect location of candidate sites in the GIS-MCDA based facility-selection studies. The large size of Site A does not rule out phased development, but should be investigated with detailed fieldwork prior to final site selection, which should include investigation of engineering conditions, drainage, land ownership, accessibility, environmental constraints and economic feasibility.

The results can be added to the development of the use of GIS-MCDA for spatial decision making in agricultural and infrastructure planning. Oluwanimifise and Anyaechie (2025) used GIS-MCDA for landfill-site selection in Ibadan, Nigeria, and Ajibade et al. (2020) applied GIS-MCDA in the process of dam-site selection. The case studies prove that the use of spatial criteria as part of a GIS environment for facility-siting

decisions can be valuable. In agriculture, Mathenge et al. (2022) found that there was a focus on agricultural production and scarcity of publications that were based in sub-Saharan Africa. The application of the present study is broader than the above since it shows specifically the use of GIS-MCDA in the preliminary planning of Grain Storage Facilities in Jalingo LGA with the aid of Earth observation and spatial data.

The study has certain limitations which should be kept in mind in interpreting the results. There was no formal assessment of the statistical accuracy of the LULC classification done, e.g., no confusion matrix was created, nor was an overall accuracy or Kappa coefficient calculated. However, classification was confirmed by visual comparison with high-resolution imagery and Google Earth Pro. This is an excellent verification process, but it does not yield a quantitative statistic of the accuracy of classification. Secondly, the AHP analysis was carried out using only one set of pairwise comparison judgements and sensitivity analysis was not performed. In the study by Chen et al. (2010), it was shown that the result of GIS-MCDA is sensitive to the criterion weights. This can result in different suitability patterns with alternative defensible weights. Since the results of the LULC classification and sensitivity analysis of the AHP weights may be used in future to assess the robustness of the identified candidate locations, it is important that this was considered and included in future studies.

CONCLUSION

The study developed and applied a GIS-based MCDA model weighted using AHP to determine the optimum position for the grain storage facilities in Jalingo LGA of Taraba State. The proximity of agricultural land and road access were the most influential criteria (62.3% combined weight), with around 84.7% of the LGA classified as "Suitable" or "Highly Suitable," and three potential sites were identified and ranked. The Consistency Ratio is 0.036, which indicates that the AHP weighting is internally reliable. The findings herein have shown that easily available Earth Observation data (Landsat 9, SRTM) coupled with widely-available GIS software can be used to create a defensible and replicable decision-support tool for siting grain storage facilities in data-scarce Local Government Areas, addressing a facility type (grain store) and geographic context (local government areas) not studied earlier.

The value of this study is three-fold. First, it extends the existing GIS-MCDA facility-siting literature, previously applied to landfill siting (Oluwanimifise & Anyaechie, 2025) and dam siting (Ajibade et al., 2020), to grain storage siting, a facility type and geographic context not previously analysed using GIS-MCDA. Second, it offers an empirical set of criterion weights derived from the AHP process and a reclassification scheme that can be used in grain storage siting projects, and can be replicated in other agro-ecological zones of Taraba State and the north-eastern region of Nigeria generally. Third, the study provides three ranked candidate sites, each with coordinates, as direct output to the regional agricultural planning authority to action.

Site A, with the largest area and highest suitability ranking, is recommended for the first project, balanced against the need to weigh economies of scale from concentrated development against the accessibility benefits of reaching more peripheral farming communities; given the limitations of 30 m resolution EO data in capturing fine-scale drainage conditions, complementary investment in rural feeder roads and a site-specific hydrological assessment during detailed engineering design are also advised.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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