Site Suitability Mapping for Cattle Ranch in Selected Local Government Area of Benue, Nigeria

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Abstract

Site suitability mapping is a prerequisite for optimum and sustainable cattle production which ensures food and reduce incessant clashes among the farmers-headers. This study mapped the criteria and examined the suitability site for cattle ranching in some selected Local Government Area of Benue State, Nigeria, using GIS-based Multi-Criteria Decision Analysis (MCDA). Remote sensed data from Landsat 8 OLI_TIRS, Shuttle Radar Topographic Mission (SRTM) elevation data, Sentinel-2 imagery, European Soil Data Centre (ESDC), NASA TRMN Satellite, OpenStreetMap, and administrative boundaries. GIS reclassification and, analytical hierarchical process (AHP) was applied. The criteria used for suitability assessment were Land Use/Land Cover (LULC), Normalized Difference Vegetation Index (NDVI), slope, soil type, proximity to roads and rivers, rainfall patterns, and Digital Elevation Model (DEM). ArcGIS 10.3 Software was used for the data analysis. The result of the weighted overlay analysis revealed that LULC (25%), soil (20%), and rainfall (15%) were the most influential factors, while DEM and road proximity had the least weight (5%). The results also indicate that 17% (34,786 Ha) of the study area is highly suitable, characterized by dense, 55% (113,337 Ha) is suitable, with moderate vegetation, 28% (57,197 Ha) is moderately suitable, featuring variable vegetation while less than 1 Ha was deemed unsuitable due to steep slopes (>12°), poor soils (Lithosols), and water scarcity. The study recommends prioritizing development in highly suitable zones while implementing gradual improvements in moderately suitable areas to enhance cattle ranching productivity and reduce land-use conflicts.

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Introduction

The uneven distribution of resources and insecurity resulting from climate change, coupled with ethnic, religious, and identity politics, have strained peaceful coexistence between farmers and herders in West and Central Africa over the past few decades (Adams et al., 2023). However, farmer–herder clashes posed a significant threat to security and stability in the Sahelian and savannah dryland regions. The Conflict between farmers and herders in Nigeria constitutes one of the greatest threats to peaceful coexistence, and national security, as well as to efforts aimed at achieving sustainable national development (IPCR, 2021). In recent times, Nigeria has witnessed a series of violent communal clashes arising from the activities of who move about daily with their cattle in search of water and greener pastures to feed their animals. Conflicts and violent clashes between farmers and nomadic cattle herders have been a common feature of economic livelihood in West Africa (Tonah, 2016). In most communities, the conflict between herders and farmers is caused by issues related to cattle grazing and crop destruction, or disputes over land ownership (Adichie, 2021). The upsurge and incessant resource conflicts resulting from boundary disputes in the tropics have led to loss of life, property, and environmental degradation, as also witnessed in some developed countries (Tartes & Watt et al., 2015). It was suggested that some of the land use conflicts among the teeming rural agrarian communities in the northern parts of the country are often wrongly attributed to ethnoreligious while ignoring the salient role that environmental degradation, climate change, and urbanization play in exacerbating the conflicts (Whanda et al., 2016).

The issue of violent clashes and instability between farmers and nomadic

herders across the regions in Nigeria has become a major focus of the Nigerian Government and international and National or indigenous development organizations. This to a large extent, if not nipped in the bud, may affect the achievement of SDG 2, which aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture by 2030. The clashes have been increasing exponentially to the dismay of helpless Nigerians (Akpaki, 2012). It is essential to note that environmental factors also contributed to the recurring or yearly clashes between farmers and herders. For instance, most of these incidents usually occur during the dry season when forage and water are scarce and insufficient to feed the cattle. Resource use conflicts between farmers and herders have been in most countries of the Sahelian African region due to rapid population growth and the escalating effects of climate change (Day & Caus, 2020). Consequently, food security in many developing countries has been threatened by several factors such as unequal land distribution, ineffective land reform policies, inefficient agricultural value chains, and an increasing number of climate disasters (Nnaji, et al., 2022).

Cattle ranching is one of the branches of agriculture that involves the rearing and breeding of cattle in enclosed areas for beef production. The practices might also include meat production, milk production, working animals and the management and care of cattle to ensure well-being and productivity. Livestock production is highly dependent on rangeland. Rangeland is a specific type of land cover that consists of grasslands, and shrubby vegetation along provides service as grazing land for cattle and wildlife (Squires, 2010). The area where ranching takes place can have significant environmental impact, such as land degradation and greenhouse gas emissions. In this regard, sustainable practices are being explored to minimize these effects (EPA, 2022).

Site suitability is one of the methods to identify and determine the most suitable location for specific target or purpose, providing the best site for end

users. This is widely used in various disciplines as the method could be applied by planners, industrialists, agriculturalists and contractors. Intergovernmental Panel on Climate Change (IPCC, 2023) described site suitability as a multifaceted and dynamic concept that evolves with technological, environmental, and societal changes. The specific criteria used in the analysis will depend on the purpose of the mapping and the characteristics of the site in question. This implies that as the world transitions from the manual application of real-world processes to digital ones, planners, developers, and policymakers face new challenges, such as climate change, urbanization, and technological advancements, and the criteria for assessing site suitability continue to expand. A wrong location leads not only to increased production costs but also triggers environmental issues, hindering industry growth (Emeksiz & Yuksel, 2022). Hence, choosing the appropriate location for the livestock industry's development is proposed as a practical approach to reducing environmental, social, and economic (Maakaven et al., 2023)

Recent studies have employed GIS-based multicriteria decision analysis (MCDA) and remote sensing techniques to evaluate rangeland suitability for livestock production, though critical gaps persist in their methodological approaches.

Abel et al. (2022) assessed rangeland suitability for cattle, sheep, goats, and camels in the Bale lowlands using criteria such as land-use/land-cover (LULC), rainfall, water accessibility, slope, and soil types. Their findings classified areas of 4,112 km² (cattle), 16,311 km² (sheep), 6,643 km² (goats), and 9,820 km² (camels) as highly suitable, with marginal to moderate suitability covering larger expanses. However, this study overlooked vegetation quality (NDVI for forage assessment), elevation (critical for climate stress avoidance), and road accessibility (logistical feasibility), which are vital for holistic ranch planning. Similarly, Kardam et al. (2022) applied a geospatial MCDA approach to identify cattle ranch sites in Bauchi State, Nigeria, reporting 41%

of the land as suitable. Despite replicating Abel et al.'s framework, this study also neglected vegetation dynamics, elevation thresholds, and proximity to infrastructure key factors influencing ranch productivity and operational viability. Tsegaye (2024) expanded the criteria to include altitude (elevation), slope, LULC, soil, and water availability in Afar, Ethiopia, yet still excluded NDVI-based forage analysis and road networks. The results highlighted that 69.26% of the area was presently unsuitable, underscoring the need for more granular data integration.

A parallel study by Masha et al. (2024) on Mountain Nyala habitat suitability in Bale Mountains National Park incorporated elevation, slope, vegetation, and proximity to roads/rivers demonstrating the value of these factors for conservation. However, livestock-focused studies like Abel et al. and Kardam et al. failed to adopt similar comprehensive criteria, particularly NDVI for grazing quality and road accessibility for market linkages.

Site suitability is one method practiced in most developed countries to bridge the existing gaps in conflict between farmers and herders. It can reduce the occurrence and recurrence of issues among the parties. This study identified and mapped criteria for the siting of cattle ranching sites and determined the suitable sites for cattle ranching with the following research question, what are the criteria for the siting of cattle ranching sites and where are the suitable sites for cattle ranching?

Study Area and Methodology

The study area for this research is Apa and AGATU local government area (LGA) of Benue State, Nigeria, with headquarters in Ugbokpo and Obagaji town respectively. APA is located between latitudes 7°20' 00'' N and 8°20' 00'' E. It is bounded in the North by Agatu LGA, to the East by Gwer West, to the south by Otukpo, and West by Omala LGA of Kogi State while Agatu LGA is located between latitudes 7°40' 00'' N and Longitude 8°10' 00'' E (Figure 1). It

is bounded in the north by Nasarawa and Apa LGA to the south and Kogi to the east and Gwer West to the west. Geographically, Benue State lies within the Middle Belt region of Nigeria and is characterized by diverse landscapes. The southern part of the state features lowland areas and river valleys, including the Benue River, which is a significant waterway in the region. Towards the north, the terrain gradually transitions into the Guinea savanna, characterized by grassland plains and scattered woodland.

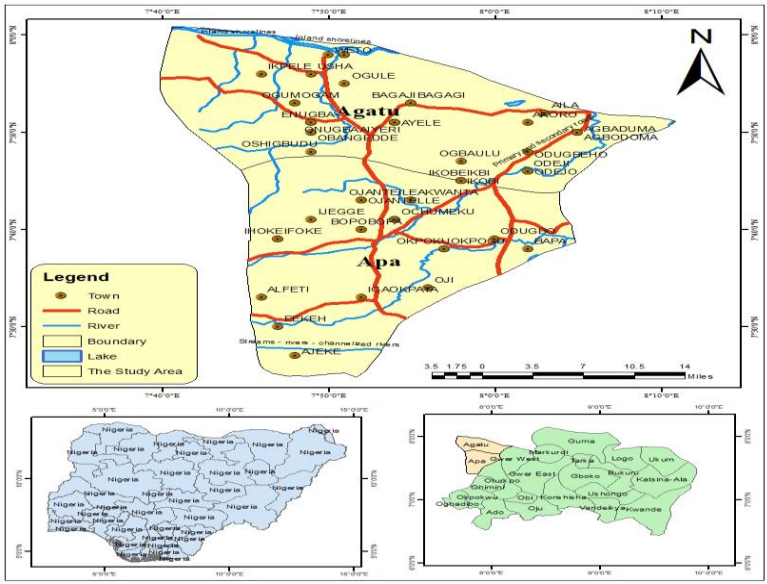

Fig. 1: The study area map. Source: Modified and adopted from administrative map of Benue State (2024)

Types and Sources of Data

The data used for this study were mainly secondary data. This is explained in table 1. To map suitability for cattle ranching in the study area, the key factors that play a significant role were analyzed (reclassified) for the purpose of cattle ranching.

Table 1: Data types, sources and purpose

S/N	Data	Resolution/Scale	Source	Purpose
1.	Landsat 8 OLI_TIRS (2025)	30m ™	United States Geological Survey (USGS). (http://glovis.usgs.gov)	For the creation of land use/land cover map
2.	Shuttle Radar Topographic Mission, (SRTM)	30m ™	United States Geological Survey (USGS) (http://glovis.usgs.gov)	For the creation of slope and elevation maps
3	Sentinel – 2 Data	10m	Sentinel Data Hub	NDVI creation
4	Hydrological Data		NASA TRMN Satellite www.earthobservatory.nasa.gov.ng	For study area water map
5	Soil Map	1:50,000	European Soil Data Centre https://esdac.jrc.ec.europa.eu/content/soil-map-nigeria	For the creation of soil map
6	Road Map	0.15m	Google Earth map	For criteria mapping
7	Rainfall		Nigeria Metrological Agency	For the criteria mapping
8	Administrative Map		Extracted from Nigeria Administrative map	For the delineation of boundaries

Source: Author's Compilation 2024

Methodology

Satellite imagery Landsat 2024 of the study area was obtained from Earth Explorer and processed in ArcGIS 10.8 by using supervised (Maximum Likelihood) classification method. The classification was done via band composition and grouped into bareland, built up, vegetation and water body.

The Normalised Digital Vegetation Index (NDVI) was determined by calculating satellite bands (NIR and Red) using this formula:

$$NDVI = \frac{(NIR-Red)\ (NIR+Red)}{(NIR+ Red)\ (NIR- Red)}$$

The slope data was generated from digital elevation model using spatial analysis toolbox in ArcGIS Software. The output of the result comes in a raster layer which are usually in degrees or percentage.

Soil data was obtained from European Soil Data Centre database. The study area soil was delineated and used for the analysis.

Rainfall data for the year 2024 was obtained from Nigeria Metrological Agency. The data were saved in Microsoft Excel and saved in Command Delimited. The data was imported into ArcGIS environment. Therefore, Inverse Distance Weighting method of interpolation was used to generated the rainfall data of the study area.

Road data were obtained from OpenStreetMap. The study area of interest was delineated while the rivers of the area were extracted from existing hydrography datasets (NASA TRMN Satellite). For the final suitability map, the weight of factors influencing site suitability for cattle ranching were assigned. Pair wise comparison which is a sub-set of Analytic Hierarchy Process (AHP) method in which the scales were compared in pairs and their importance to each other were determined by using nine scale Saaty matrix. A pairwise comparison was used as the input to establish a ratio matrix, and the relative weights were created as the output Malczewski, (2006). Assigning of normalized weights of each layer and weights of attributes in each layer were done using the Analytic Hierarchy Process (AHP) of Saaty (1980). Table 42 shows the AHP scale for pair wise comparisons.

Table 2: The analytic hierarchy process (AHP) scale for pair-wise comparison

Intensity of importance	Definition	Explanation
1	Equal importance of i and j	Two activities contribute equally to the objective

Intensity of importance	Definition	Explanation
3	Weak importance of i over j	Experience and judgment slightly favor one activity over another
5	Strong importance of i over j	Experience and judgment strongly favor one activity over another
7	Demonstrated importance of i over j	An activity is strongly favored and its dominance is demonstrated in practice
9	Absolute importance of i over j	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values the two adjacent judgments	When compromise is needed

Source: Saaty (1980)

The matrix in Table 3 was normalized by dividing each number in the column by the sum of the columns.

$$\bar{a}jk = \frac{a_{jk}}{\sum_{i=1}^{m} a_{jk}}$$

Where $\bar{a}$ is value in the matrix, j is column number, k is row number, i is the theme while m is the total number of themes. To produce thematic weights wj, from the normalized values, Equation (2) will be used. The normalized weights were then ranked in descending order.

$$wj = \bar{a}jk/n$$

It is important to check the consistency of the pair-wise comparison. Consistency check will be done following the procedure by Saaty (1980)

Where:

$$Consistency\ ratio\ (CR) = \frac{\mathrm{CI}}{\mathrm{RI}}$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n-1}$$

Where RI is the random index

Table 3: Random index values for n ≤ 10

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

Source: Saaty (1980)

A consistency ratio (CR) of 0 indicates perfect consistency of pair-wise comparison. Saaty (1980) suggested that an acceptable CR should be less than 0.1, and that where values of CR exceed 0.1, the pair-wise comparison will be too inconsistent and thus unreliable.

All the thematic layers (LULC, NDVI, DEM, soil, slope, rainfall, proximity to river and road accessibility maps) were reclassified into five different classes depending on their influence on cattle ranching. All the data formats were converted to raster at a 30m resolution for criteria standardization and reclassified into a common evaluation scale with values ranging from 1 to 9. The value of 9 was considered highly suitable, while that of 1 was considered very low suitable for all factors considered in the weighted overlay analysis. Table 3 shows the suitability classification according to FAO (1997).

Table 4: Suitability classification

Score	Level of suitability
9	Highly suitable
7	Suitable
5	Moderately suitable
3	Less suitable
1	Not suitable

Source: FAO, (1997)

The reclassified thematic layers were integrated, and weighted overlay was conducted in the spatial analysis tools within the ArcGIS package (version 10.8) to produce the overall site suitability map for the cattle ranch in the study area. In weighted overlay, the preferred criteria are processed and input with different weighting (%) applied to each criterion obtained by using AHP. The relative weight of the criteria used are determined through the effect of each factor on urban development.

Results and Discussion

Determinants of site suitability for cattle ranch

These criteria are land use and landcover, normalized digital vegetation index, slope, soil, rainfall, road, river and DEM thematic map for each of these criteria were produced in ArcGIS 10.7 and the result were presented in Tables 6 to 16 and Figures 2 to 11.

Land use and land cover

The table provides a classification of land use and land cover (LULC) with their respective suitability scores, area coverage, and percentage distribution. The result of the LULC map of the study area is presented in Table 6.

Table 6: Land use and landcover of the study area

Name	Score	Level of suitability	Area (Ha)	%
Water	1	Not suitable	55776.77	26
Built up	6	Moderately suitable	114650.95	54
Vegetation	9	Highly suitable	42995.13	20
Total			213422.87	100

LULC results indicates that water has (26%) which are not suitable. This shows the presence of water in the area, which could influence hydrological studies and land use restrictions. Built-up areas occupied (54%) which are moderately suitable. The dominant coverage indicates high urbanization which may require infrastructure planning while (20%) of the study area are considered to be highly suitable with an area of 42,995.13. The 20% coverage suggests that vegetation is limited compared to built-up areas, which could raise concerns about deforestation, habitat loss, or carbon sequestration capacity.

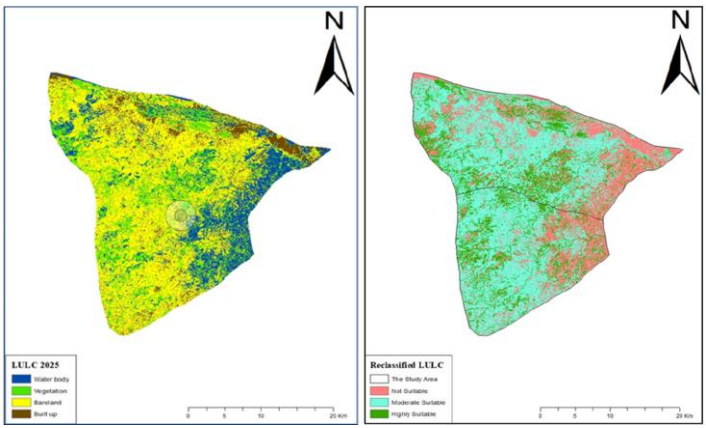

Fig. 2: Reclassified land use land cover map of the study area. Source: Author's analysis (2024)

Normalized digital vegetation index

NDVI measures vegetation health and density, making it a key indicator of forage availability, the most critical factor for successful cattle operations

Table 7: Normalized digital vegetation index of the study area

Category	Score	Level of suitability	Area (Ha)	%
0.0 - 0.2	3	Less suitable	8041.14	4
0.3 - 0.4	4	Moderately suitable	44029.44	21
0.5 - 0.6	8	Suitable	137785.61	65
0.7 - 1.0	9	Highly suitable	23569.74	11
Total			213425.93	100

NDVI results indicate that 4% of the total area (8,041 Ha) is less suitable. This represents bare soil, rocks, or very sparse vegetation implying a high risk of overgrazing and soil erosion. 21% are considered to be moderately suitable for cattle ranch. However, the area would require rotational grazing. 65% of area (137,786 Ha) are suitable. This shows healthy and productive vegetation and excellent year-round grazing could be established in this region while 11% of area (23,570 Ha) are highly suitable.

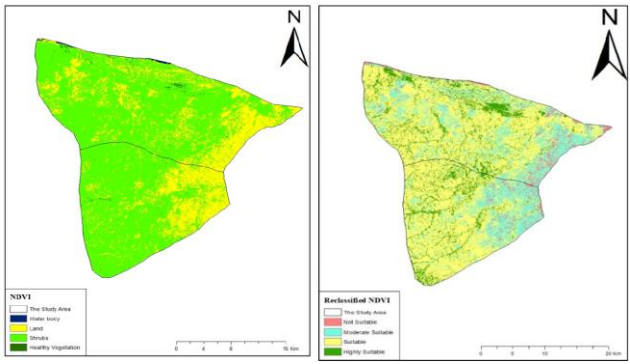

Fig. 3: Normalized digital vegetation index map of study area. Source: Author's analysis (2024)

Slope map

Slope significantly impacts ranch management through its effects on animal movement between points, grazing patterns, and erosion risk. This table presents a slope classification of the study area, which is crucial for evaluating terrain suitability for cattle ranching operations

Table 8: Slope classification of study area

Category	Score	Level of suitability	Area (Ha)	%
> 45%	3	Not suitable	2145.91	1
12 - 40%	4	Less suitable	6929.85	3
6 - 12%	6	Moderately suitable	13020.23	6
3 - 5%	8	Suitable	25261.81	12
0 - 3%	9	Highly suitable	164283.43	78
Total			211641.22	100

This result indicates that more than 45% of the Slope, which represents 1% of the total area (2,146 Ha), is not suitable for cattle ranching simply because the area has extremely steep terrain that could be dangerous for cattle to move easily from one point to another. 3% of the area (6,930 Ha) is less suitable, 6% of the area (13,020 Ha) is moderately suitable, 12% of the area (25,262 Ha) could have minimal restrictions on cattle movement, while 78% of the area (164,283 Ha) is highly suitable. This is ideal terrain for cattle operations, with optimal grazing distribution and the lowest erosion risks.

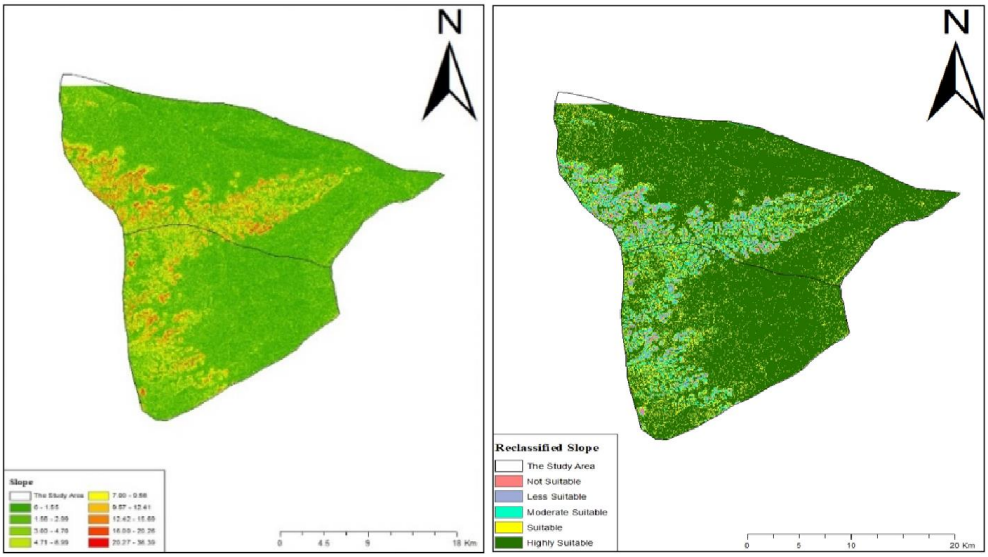

Fig. 4: Slope map of study area. Source: Author's analysis (2024)

Soil map

This table presents a soil classification of the study area, which is fundamental for evaluating land suitability for cattle ranching operations. Soil type has a significant impact on ranch productivity, affecting pasture growth potential and water retention capacity.

Table 9: Soil map of study area in degrees

Category	Score	Level of suitability	Area (Ha)	%
Orthic acrisol	6	Less suitable	49574.10	24
Lithosol	7	Moderately suitable	5097.88	2
Chromic vertisol	8	Suitable	75128.58	36
Chromiv luvisol	9	Highly suitable	81068.01	38
Total			210868.57	100

Soil results indicates that 24% of total area (49,574 Ha) are less suitable which

could have a low nutrient retention capacity, 2% of area (5,098 Ha) are moderately suitable which are shallow soils over bedrock, 36% of area (75,129 Ha) are suitable which are consider to be clay-rich, high nutrient content have the ability to retain water, 38% of area (81,068 Ha) are highly suitable. These areas are deep, well-structured soils and retain water. These premium soils are good for cattle ranching.

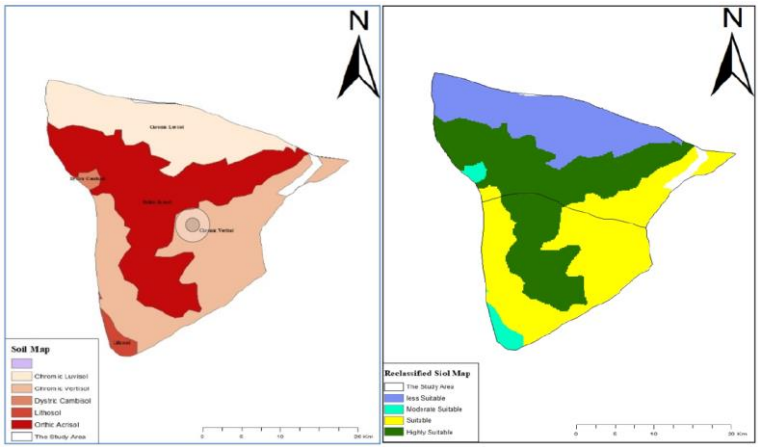

Fig. 5: Soil map of study area. Source: Author's analysis (2024)

Rainfall map

This table presents a rainfall distribution analysis of the study area, which is crucial for evaluating climatic suitability for cattle ranching operations. Rainfall patterns directly impact pasture growth and quality, water availability for livestock and forage production consistency. ppp

Table 10 Rainfall Map of the Study Area in Degree

Category	Score	Level of Suitability	Area in (mm)	%
400 - 600 mm	6	Moderately Suitable	184121510.90	9%
600 – 800 mm	8	Suitable	1217474311.66	60%
800 – 1200mm	9	Highly Suitable	640663247.76	31%

Category	Score	Level of Suitability	Area in (mm)	%
Total			2042259070.31	100

Rainfall result indicate 9% of total area (184,121,511 mm) are moderately suitable with the characteristic of having semi-arid conditions and seasonal rainfall variability, 60% of area (1,217,474,312 mm) are suitable which tends to have a reliable annual rainfall good pasture growth potential, 31% of area (640,663,248 mm) are highly suitable. this represents abundant rainfall and lush pasture growth with low drought. They are ideal for intensive grazing systems.

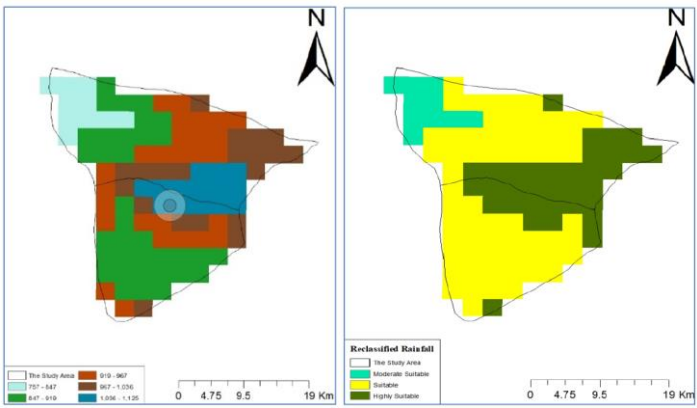

Fig. 6: Rainfall map of study area. source: author's analysis (2024)

River Proximity Map

This table evaluates the study area's proximity to rivers, a critical factor for cattle ranching operations. Water accessibility significantly impacts livestock water requirements, pasture quality and distribution and ranch infrastructure planning.

Table 11: River proximity map of the study area in degree

Category	Score	Level of Suitability	Area (Km2)	%
5 - 8 km	4	Less Suitable	1528224638.59	44
3 - 5 km	6	Moderately Suitable	999434494.13	29
1 - 2 km	8	Suitable	638704367.97	18
< 1 km	9	Highly Suitable	313621832.97	9
Total			3479985333.67	100

River results indicate 44% of total area (1,528 km²) are less suitable which distance to water point, 29% of area (999 km²) are moderately suitable which could be manage but somehow suboptimal water access, 18% of area (639 km²) are suitable with access to good natural water while 9% of area (314 km²) are highly suitable with an immediate water access and this enables intensive grazing management.

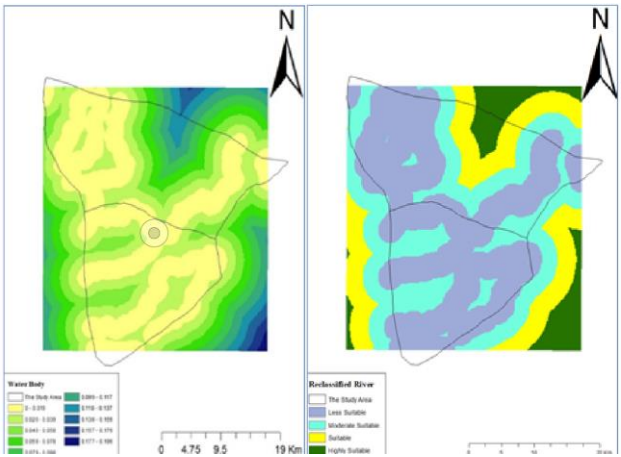

Fig. 7: River proximity network map of study area. Source: Author's analysis (2024)

Proximity to Road

This table evaluates the study area's proximity to roads, which is very a crucial for cattle ranching operations. This road proximity affects transportation

logistics and operational efficiency.

Table 12: Proximity to road

Category	Score	Level of Suitability	Area (km2)	%
< 1 km	4	Less suitable	2275.96	65
10 - 15 km	6	Moderately suitable	572.06	16
5 - 10 km	8	Suitable	454.41	13
2 - 5 km	9	Highly suitable	177.53	5
Total			3479.96	100

Road is one of the criteria that should be considered in site suitability analysis for urban development. Table 4.9 indicates that <1 km 65% of total area (2,276 km²) are less suitable due to the fact that they extremely close to roads which could presents multiple challenges, 16% of area (572 km²) are moderately suitable which could be manageable on transport cost but somewhat balance between access and isolation, 13% of area (454 km²) is suitable which is ideal distance for most ranching operations and good market access without disturbances while only 5% of area (178 km²) is highly suitable. This location offers premium facilities for intensive operations and excellent access for daily livestock management.

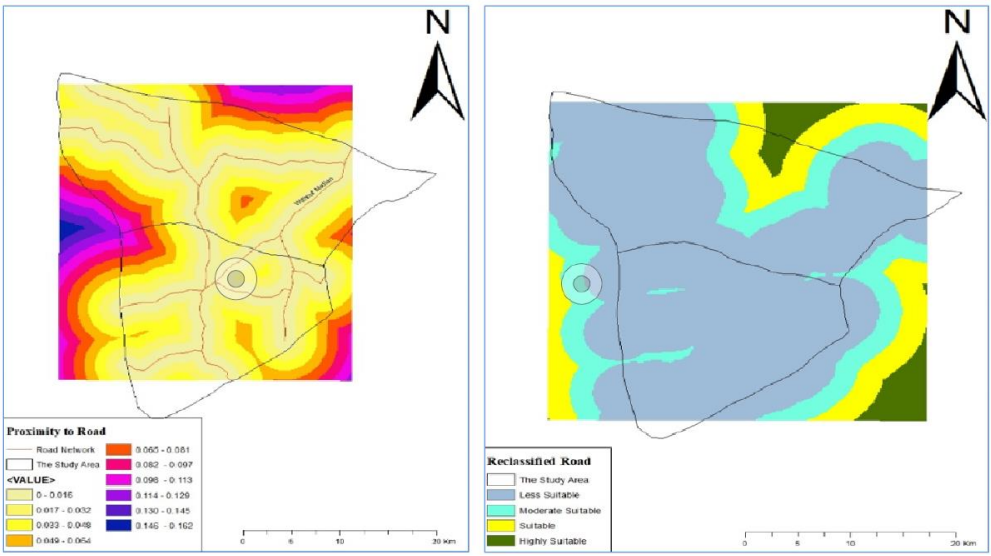

Fig. 8: Road network map of study area

Digital elevation model

Table 13: Elevation of the study area

Category	Rank	Level of suitability	Area in (Ha)	%
250 – 400 m	5	Moderately suitable	26496.40	12
150 – 250 m	7	Suitable	43224.60	21
45 – 150 m	9	highly suitable	142534.49	67
Total			212255.49	100

The lower the elevation, the better the area for cattle ranching. The DEM results that 12% of the total area (26496.40 Ha) is moderately suitable, with an elevation of 250–400 m. 21% of the area (43224.60 Ha) is suitable, while 67% of the area (142534.49 ha) with an elevation of 45–150 m is highly suitable.

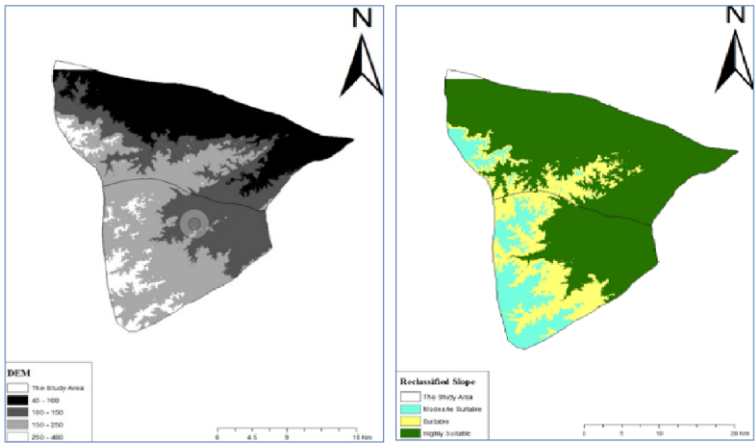

Fig. 9: Reclassified digital elevation model of study area. Source: Author's analysis (2024)

Multi-Criteria Weighting

A total of six (8) different thematic layers were considered for this study. All the thematic layers were compared with each other in a pair-wise comparison matrix based AHP, in Microsoft Excel and the results are presented in Tables 4.8.

Table 14: Pairwise comparison matrix of factors influence cattle ranch suitability

Matrix		LULC	NDVI	Slope	Soil	Rainfall	River	Road	DEM
		1	2	3	4	5	6	7	8
LULC	1	1	3	2	3	3	3	2	3
NDVI	2	1/3	1	1	1	1	2	1	2
Slope	3	½	1	1	1	2	2	1	2
Soil	4	1/3	1	1	1	4	6	4	3
Rainfall	5	1/3	1	½	¼	1	5	4	3

River	6	1/3	1/2	½	1/6	1/5	1	1	2
Road	7	½	1	1	¼	1/4	1	1	3
DEM	8	1/3	1/2	½	1/3	1/3	1/2	1/3	1

AHP is the most common and well-known GIS based multi criteria decision analysis technique for conducting suitability analysis. This technique aid in the integration of all the thematic layers used in the research. The associations of these influencing factors are weighted based on their influence on land suitability for urban development. A parameter with a high weight has a significant impact, while a parameter with a low weight has a minimal impact on suitability for urban development. The weight of each parameter was assigned according to Saaty's scale (1–9) of relative importance value. The Consistency Ratio (CR) estimated for the comparison matrix was 0.0, which falls within the accepted interval of consistency (<10%), indicating that the relative weights were properly chosen in this site suitability analysis model. The pairwise comparison matrix was normalized, and the weight of each parameter used for generating the suitability map was obtained by calculating the average of the normalized values on each row, as indicated in Table 4.9. LULC has the highest weight of 0.25 (25%) while DEM and road has the lowest weight of 0.05 (5%).

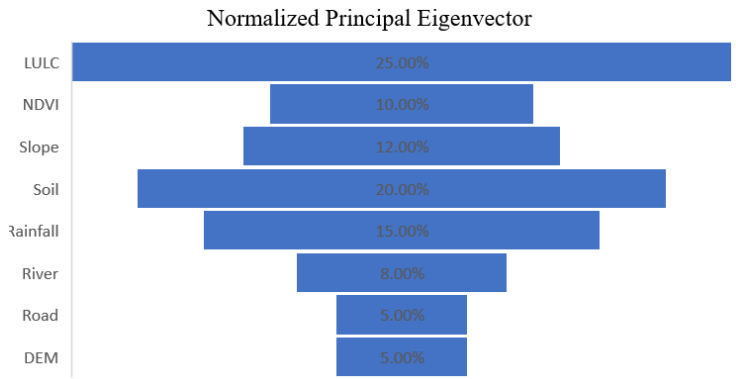

Fig. 10: Normalized principal eigenvector

Table 15: Normalized pairwise matrix

Criteria	LULC	NDVI	SL	SO	RF	RV	RD	DEM	Weight
LULC	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.251	0.25
NDVI	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.1
Slope	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.12
Soil	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.2
Rainfall	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.15
River	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.08
Road	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.054	0.05
DEM	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.05
	1	1	1	1	1	1			1

The suitability map for cattle ranch in the study area was computed by using the weighed overlay tool and the result

Determining the site Suitability Map for Cattle Ranching

This final suitability classification integrates all critical factors (LULC, NDVI,

soil, slope, rainfall, river, road, and DEM) in order to identify the optimal locations for cattle ranching operations in the study area.

Table 16: Site suitability map for cattle ranch in the study area

Rank	Description	Area (Ha)	%
4	Less suitable	0.9835	0
5	Moderately suitable	57197.0951	28
7	Suitable	113337.325	55
9	Highly suitable	34786.015	17
Total	Total	205321.4193	100

This indicates that (17%) of area 34,786 Ha are highly suitable with ideal vegetation cover (NDVI 0.6-1.0), gentle slopes (0-3°), fertile soils (Chromic Luvisols/Vertisols), Optimal rainfall (800-1200mm), close to water sources (<1km), and (55%) area of 113,337 Ha are suitable with good vegetation (NDVI 0.4-0.6), Moderate slopes (3-5°), Quality soils (Chromic Vertisols), Reliable rainfall (600-800mm), Reasonable water access (1-2km), and (28%) of area 57,197 Ha are moderately suitable, variable vegetation (NDVI 0.2-0.4), Some slope challenges (6-12°), Soil limitations (Orthic Acrisols), Seasonal water constraints while <1 Ha area are less suitable with Steep slopes (>12°), Poor soils (Lithosols) and Water scarcity, remote locations.

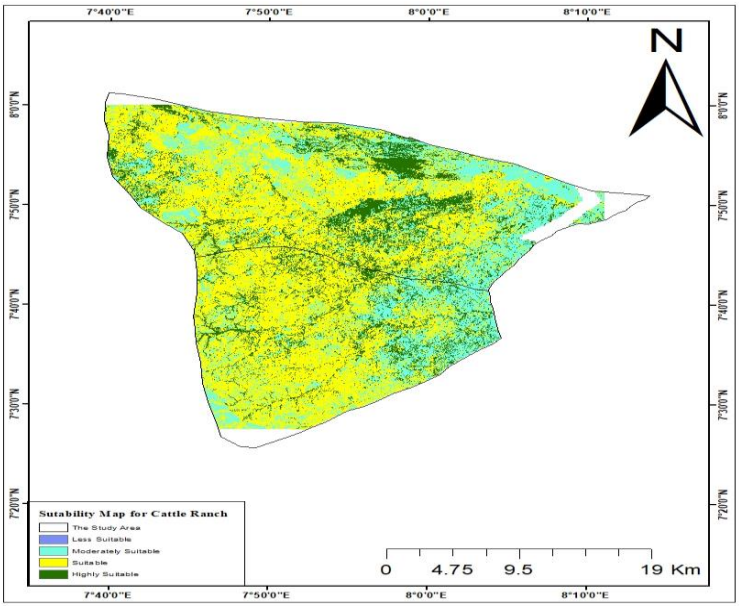

Fig. 11: Site suitability map for cattle ranch in the study area. Source: Author's analysis (2024)

Discussion

The suitability analysis for cattle ranching in the study area revealed significant spatial variations in land potential across the study area. Essentially, the findings demonstrate that only 17% (34,786 Ha) of the study area could be considered as highly suitable. These areas are characterized by optimal conditions with dense vegetation cover (NDVI 0.6-1.0), gentle slopes (0-3°), fertile Chromic Luvisols/Vertisols soils, reliable rainfall (800-1200mm), with the accessibility of water (<1km). These areas aligned with global benchmarks for intensive cattle operations, where such combinations of biophysical factors support year-round grazing without degradation risks (Zhang et al., 2024).

However, the majority of the study area (55%, 113,337 Ha) falls into the suitable category for the cattle ranching, featuring good vegetation (NDVI 0.4-0.6), moderate slopes (3-5°), and adequate water access (1-2km). While

productive, these lands require careful management through rotational grazing systems in other to prevent overuse, as demonstrated in similar ecological zones by Abel et al. (2022). The presence of Chromic Vertisols in these areas provides favourable water retention capacity, though their heavy texture may require occasional soil amendments to maintain permeability.

Notably, 28% (57,197 Ha) of the area presents moderate suitability due to multiple constraints, including variable vegetation (NDVI 0.2-0.4), steeper slopes (6-12°), and Orthic Acrisols with limited water retention. These limitations echo findings from marginal rangelands in Ethiopia, where Tsegaye (2024) documented similar challenges requiring targeted interventions. The extremely limited unsuitable areas (<1 Ha) with steep slopes (>12°), poor Lithosols, and water scarcity confirm global observations that such terrain is universally inappropriate for ranching operations (Lillesand et al., 2023).

The land use/land cover analysis revealed concerning patterns, with built-up areas covering 54% of the study region, indicating significant urbanization pressures. This urban expansion threatens remaining suitable rangelands, mirroring land-use conflicts documented by Kardam et al. (2022) in Nigeria's ranching regions. Water accessibility emerged as another critical factor, with 44% of areas located too far from reliable water sources, potentially exacerbating drought vulnerability during dry seasons.

Road accessibility presented a complex trade-off. While proximity to roads (65% of area within 1km) facilitates management and market access, excessive closeness may cause disturbances affecting cattle welfare and operation viability. This paradox underscores the need for careful site selection that balances logistical needs with animal husbandry requirements, as emphasized in recent sustainable ranching guidelines (ESDAC, n.d.).

The rainfall distribution patterns further refine suitability, with 31% of the area receiving abundant precipitation (highly suitable), while 9% faces semi-

arid conditions requiring supplemental water systems. These climatic variations highlight the importance of micro-zoning within the broader suitability framework, particularly in the context of climate change adaptation.

Conclusion

This study concludes that 17% of the study area are highly suitable for cattle ranching by meeting criteria for vegetation, slope, and soil fertility. However, urbanization and water scarcity pose challenges, with 55% of land requiring managed grazing and 28% limited by soil and slope. The dominance of built-up areas (54%) signals competing land-use pressures, while suboptimal rainfall and road proximity further constrain suitability. The study recommends immediate development of highly suitable zones and gradual improvement of suitable areas. Site suitability mapping using Remote sensing and GIS should be adopted for the purpose of selecting suitable site, and this will reduce danger associated with the movement of cattle. Lastly, there should be a prioritizing of NDVI-rich zones, erosion control on moderate slopes, and water infrastructure which could enhance productivity.

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