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Geospatial-based approach to siting suitable cattle ranch in Bauchi state, Nigeria

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Abstract

The rate of urbanisation in Nigeria is 5.3%, one of the highest in the world, this is proportional to the population growth, consequently the expansion of agricultural activities. These are some of the factors that put enormous pressure on the use of land resources which led to the occupation of land which were earlier meant for cattle grazing and route for farming and construction resulting to conflict between farmers and herders. Worthy of note is the lack of forage for herdsmen, due to climate change and the encroaching Sahara Desert. Pastoralist-farmers' conflicts in Nigeria have grown, spread and intensified over the past decade and today poses a threat to national survival. There is therefore, a need to settle these pastoralists and their livestock on suitable land for grazing. A unique approach of a Geospatial information System (GIS)-based multicriteria evaluation site selection was developed which took in to account various factors to find suitable areas for siting cattle ranch in Bauchi state. It was found that about 41% of the total land mass in Bauchi state is suitable for siting cattle ranch, 33% of the land shows to be unsuitable. While the remaining 26% is moderately suitable. Therefore, it can be said that there exist more than enough suitable land to site a sustainable cattle ranch in Bauchi state in order to contain the persistent herders and farmers in the state.

Keywords: MCE; Cattle Ranch; Site selection; GIS; Remote sensing

1. Introduction

Cattle rearing constitute an important sector of the Northern economy, its development was fostered mainly through the activities of indigenous cattle dealers and herders in response to improved market opportunities. The movement of the pastoral Fulani with their penetration in to Hausa land can be traced to the fifteenth century. Their concentrations are mostly found in Sokoto, Katsina, Kano, Bauchi, Plateau and Zaria [1,2].

This transhumance has been practiced in Nigeria for centuries and is commonly constrained by threats of animal diseases; insecurity, shortage of forages and water resources for livestock [3]. The resulting gradual disintegration of the burtali (official stock migration routes) allowed indigenous farmers to claim ownership rights to fertile land and waterways which Fulani cattle had been grazing for over two centuries [7]. The situation was exacerbated by the 1978 Nigerian Land Use Decree which gave complete authority to the state and local governments to assign and lease land. The relative ease with which settled farmers could obtain the 'certificate of occupancy' demonstrating land ownership, due to their 'indigene status' and higher literacy levels, left the Fulani 'permanently on the outside of land tenure [4,5]. Several mechanisms for addressing the growing issues of land use in northern and central Nigeria have included the mapping and demarcation of cattle routes and the ongoing promotion of grazing reserve establishment [3,6,7,8]. However, despite numerous attempts by both government and international organisations to improve the land rights situation, rising tensions in northern Nigeria have resulted in 'horrific internecine violence' [9] over the last 20 years. Kaduna and Plateau States have been the worst affected, with over 10,000 deaths since 2010 [8,9].

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Towards addressing the critical issues of Nigeria's pastoralism and herd's management, the Federal Government, through the Federal Ministry of Agriculture and Rural Development is setting up 5000 Ha cattle colonies in at least 21 states of the federation equipped with all requisite infrastructure and facilities [10].

Cattle colony, Rangeland or Ranch is a piece of land dedicated to grazing livestock such as Goats, sheep, Cattle, and even Horses for commercial purposes. It is usually large with accompanying structures and facilities that services the chain of product related to the ranches [11]. It can be seen as the restriction to nomadic livestock, it is the modern way of doing cattle business. The proposed cattle colonies are targeted at addressing the contemporary issues of pastoralism and transhumance in Nigeria [12].

However, the location of a complex system as a cattle ranch requires adequate knowledge for maximum usability. GIS and Remote Sensing techniques offer a convenient and powerful platform to integrate spatially complex and different land attributes for performing land suitability analysis [13]. This study utilize GIS and remote sensing to develop a geospatial model for siting land suitable for cattle ranching in Bauchi State.

The issue of settling nomadic cattle rearers is one which has for many years generated considerable discussion in Nigeria's government circles. Since the grazing law of 1965 was enacted by the then Northern Nigeria legislative assembly and with the commencement of the First National Livestock Development Project (FNLD).

Nigeria's grazing reserve law was established in 1965. This created an area, mainly in the north, for exclusive use of the Fulani nomads to graze their animals. The law protected herders against intimidation and deprivation by sedentary cultivators [14], cattle ranchers and commercial intruders. In the same year, the northern Nigerian government, as it were, domesticated the law in the region by incorporating a Fulani amenities proposal into the grazing reserve law to protect herdsmen who lived and carried out grazing activities at the mercies of farmers [15]. The Fulani amenities proposal was the article that suggested the establishment of grazing reserves. It had also called for the improvement of Fulani welfare and the transformation of their herd management system. Over 6.5 million hectares of forest reserve and in the savannah was gazetted for that purpose. The area spanned from Sokoto, in the west, through to Bauchi, in the east, and then south to Ilorin, present day Kwara State. But an increasing population and development within the areas that were earlier marked as grazing reserves led to changes in grazing; from surpluses to subsistence and survival methods that brought to fore the present nationwide security crises [16].

The rate of urbanisation in Nigeria is 5.3%, one of the highest in the world [17]. This urbanisation isn't uniform as some states/cities record higher urbanisation than others, Bauchi Metropolis for example, experienced 56.5% increase in urbanisation from 1986 to 2016 [17]. Almost simultaneously, the population of cattle in Nigeria are believed to have doubled from 9.2 million in 1980 [18]. This two-way expansion thereby leads to competition over land resources which led to the occupation of land which were earlier meant for cattle grazing for farming and construction, but [19] argued otherwise claiming that despite Kano being one of the most densely populated states in the country, it is home to about one million cattle putting the blame of farmers-herders clashes solely on poor government policies which lead to the occupation of grazing sites and neglect of the pastoral community. Much part of the capital city, Abuja according to him, for example is also believed to be part of the grazing route as there was no plan to relocate the capital from Lagos to Abuja when the grazing law was enacted in 1965 [20]. In search of pasture, herders often trespass farmlands which may or may not have been located on the grazing route/reserve. Farmers often launch counter offensive as in most circumstances they see the Fulani as occupiers and invaders of their ancestral lands [21].

Pastoralist-farmers' conflicts in Nigeria have grown, spread and intensified over the past decade and today poses a threat to national survival. Thousands of people have been killed, communities have been destroyed and so many farmers and pastoralists have lost their lives and property in an orgy of killings and destruction that is not only destroying livelihoods but also affecting national cohesion. Nigeria has about 19 million cattle, much of it in the hands of pastoralists. As violence between herdsmen and farmers has grown and developed into criminality and rural banditry, popular narratives in the form of hate speech have exacerbated the crisis [22].

[24]Argued that the incessant clashes between farmers and herdsmen is not a battle of hate but that of survival, for their cattle over insufficient pasture. This scarcity means the Fulani's now increasingly take their herd to forage further south, through towns and large villages as they traverse from north to south, roaming cattle, goats and sheep, sometimes scavenging playgrounds, school compounds, residential areas and national highways. In doing this, they intrude and cause traffic obstructions and in extreme cases, bring violence on farming communities when confronted in remote villages for trespassing on farm lands. There have been recurring clashes between herdsmen and farmers in the central Benue, Plateau, Nasarawa states and further south in Delta.

[23] Opined that, grazing reserves will be the best solution to the security situation in the country [24] also backed up this statement in their research. The traditional open Grazing may no longer be tolerated, and many forward looking countries have passed the method of raising cattle by open grazing for many decades and the result is better yield. This is due to its incompatibility with the modern society and the contemporary life style and the economy.

The Idea of cattle ranches is not foreign to the Nigeria. It was proposed by the British in 1942. There exist Obudu cattle ranch in Cross river state, Mokwa cattle ranch in Niger state, and Akunu cattle ranch. Presently established Alga cattle ranch in Ondo state. However, most grazing reserves are situated on impoverished land, with little agronomic potential [14] with inferior fodder, consisting of low-protein andropogon, brachiarria, and loudetia. For example, in Borno state, which has the largest population of livestock in Nigeria, there is hardly enough grass for year-round grazing. In the early dry-season, herds in this state browse on tree leaves, branches, and farm leftovers. At the climax of the dry season, animals eat anything green, including their own faeces and the so-called poisonous grass.

This research therefore, looked at the complexities in topography, hydrology, and land use land cover, climatic and socio-cultural requirement in the development of suitable area for sitting cattle ranch in Bauchi state using geospatial approach.

The aim of this study is to use an adaptive geospatial Model and remote sensing techniques that incorporate various spatial parameters to determine areas suitable for cattle ranching in Bauchi State. The objectives of this research are:

- To Map out the different land use and land cover over the study area;
- To identify and map constraints/criteria for the siting of cattle ranching sites;
- To carryout data standardization and scaling
- To carry out Multi-criteria Evaluation to identify suitable sites for siting ranches ;

Remote sensing and Geospatial techniques has proven in many studies to be an accurate and cost efficient method of carrying out large spatial analysis and making efficient decisions by assessing the environmental, physical and socioeconomic constraints in an area. The use of remote sensing and Geospatial techniques for resource mapping, spatial analysis and decision-making has been widely reported by many researchers and it is still applicable in this case to solve the recurring problem [25].

This study will identify areas to be used exclusively for grazing herds in Bauchi state thereby providing permanent settlements to herders where they can live with adequate security and basic amenities including hospital, school and clean water. It can also serve as source of revenue to the government and provide indirect employment to many others which might be suppliers of dairy feedings or retailers of dairy products.

This research however can serve as a model which can be applied to other northern states having similar environmental variables with Bauchi State to identify areas suitable for siting grazing reserves also known as rangelands.

1.1. Study Area

The study area is Bauchi State located in the North-eastern part of Nigeria. The state was created in 1976 when the former Northeastern state was split [26]. It is geographically located between latitudes 9° 3′ and 12° 3′ North and longitudes 8° 50′ and 11° 00′ East. The map of the study area is shown in Figure 1. The state has two distinctive vegetation zones, namely the Sudan savannah and the Sahel Savannah with rainfall between 1300 mm per annum in the south and only 700 mm per annum.

Sudan savannah vegetation covers the southern part of Bauchi state where the vegetation gets richer and richer towards the south, especially along water sources or rivers, but generally, the vegetation is less uniform and grasses are shorter than what grows even farther south, that is, in the forest zone of the middle belt. Sahel type of the savannah, which is also known as the semi-desert vegetation, becomes manifest from the middle of the state as one moves from the state's south to its north. This type of vegetation comprises isolated stands of thorny shrubs. On the other hand, the south-western part of the state is mountainous as a result of the continuation of the Jos Plateau, while the northern part is generally sandy [27].

Bauchi, state, North eastern Nigeria. Before 1976 it was a province in former North-Eastern state. Bauchi is bounded by the states of Jigawa and Kano on the northwest; Kaduna on the west; Plateau, Taraba, and Gombe on the south; and Yobe on the east. The highlands in the southwestern part of the state are an extension of the Jos Plateau. The Gongola River,

rising in the Jos Plateau, flows to the northeast, then turns southward (loosely tracing the southern half of the state's eastern boundary) to merge with the Benue River in Adamawa state.

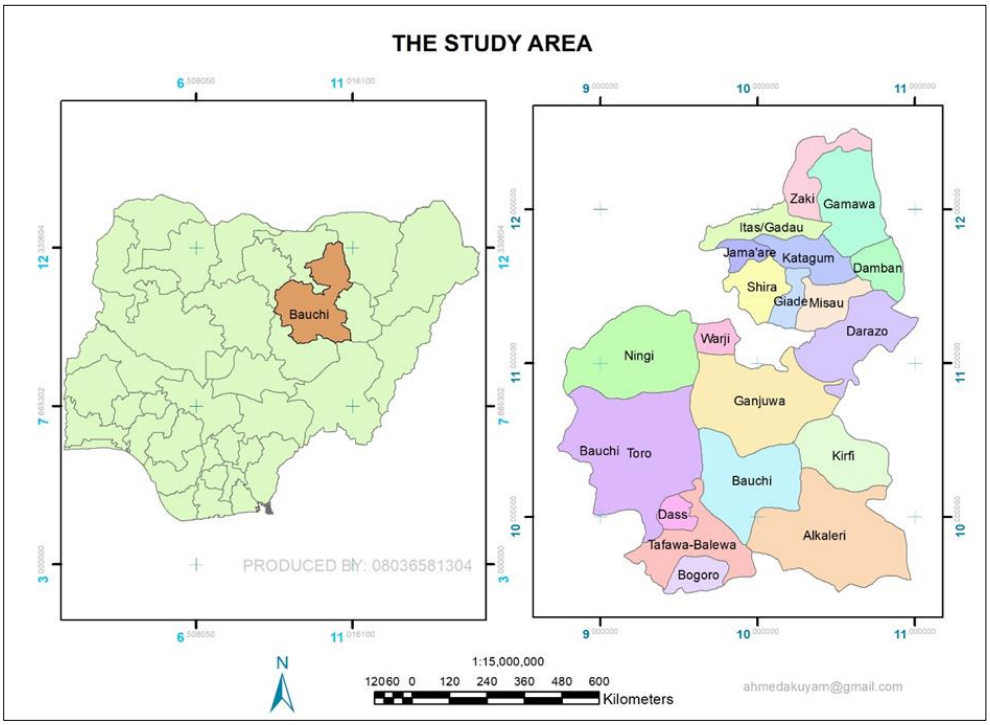

Figure 1 Map of the Study Area

2. Material and method

2.1. Datasets and Sources

Table 1 Datasets and their sources

Data	Source/Date of access	Scale/Resolution	Usage
Wold Land use Land cover data.	GIS Geography www.gisgeography.con	30 m resolution	Land use Land cover mapping
SRTM (Shuttle Radar Thematic Mission)	Earthexplorer.usgs.gov	3 arc-seconds (~90 meters) spatial resolution.	Topographic/Slope mapping
Administrative map	Mohammad Wabi Library. FPTB	Hard copy (Digitized)	State boundary map.
Protected/Conserved Areas	World database of protected areas (WDPA). www.protectedplanet.net		Protected/conserved area mapping.
Road Network			Criteria mapping.
Hydrological data (Rivers, Streams, Dams)	NASA TRMM Satellite www.earthobservatory.nasa.gov		Criteria mapping.
Rainfall/ Precipitation	NASA TRMM Satellite		Criteria mapping.

Data for this research were obtained from different sources. Table 1 presented the different datasets and their sources used in the research.

2.2. Material and software used

- ArcGIS 10.5
- Microsoft Office 2019
- ILWIS
- Handheld GPS

2.3. Research Methodology

Figure 2 shows the workflow diagram of the steps required to carry out this research.

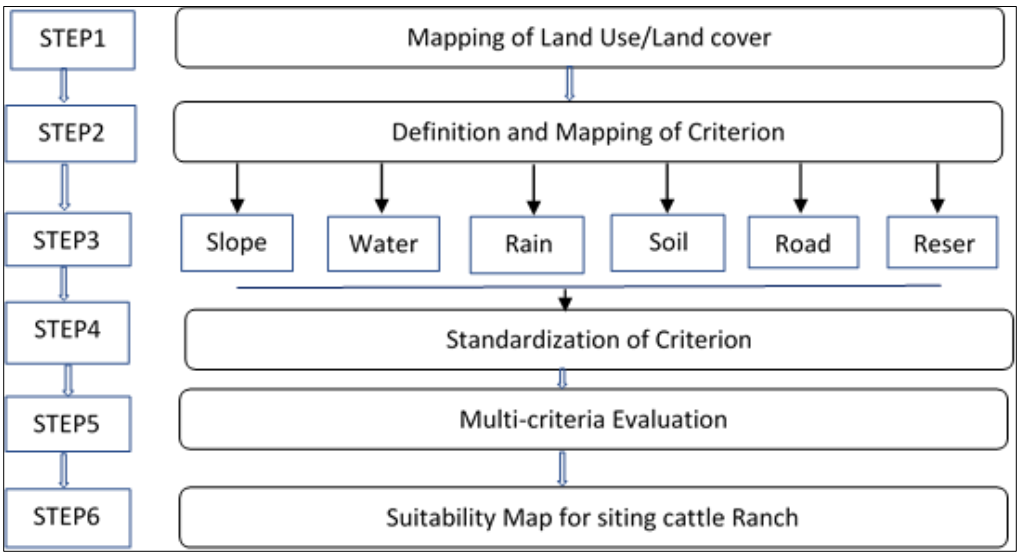

Figure 2 Methodology workflow

2.4. Land Use Land Cover of the study area

Generally LULC (Land Use / Land Cover) means classification or categorization of natural elements and human activities on the landscape within a specified time based on established scientific and statistical methods of analysis. There are various methods of classifications as well as various type of LULC elements such as: developed/Urban or Built-up Land, wetlands, Agricultural or croplands, water bodies, grasslands, bare surface, rocks formations, Forest Land and many more.

In this study, areas such as Urban or Built-up Land and are considered not suitable for siting grazing lands while grasslands and forests, and proximity to wetland and water bodies are considered suitable. Land use Land cover map of the study area was extracted from the World Land use Land cover map.

2.5. Identification and mapping of constraints/criteria

Various criterion and constraints that are important for the location of suitable sites were identified and mapped. These criterion includes Hydrological, Climatic, Geological, morphological, Topographical and socio-economic factors. Then maps of the predefined siting criterion was prepares. Criterion maps are generated based on different GIS functionality.

2.5.1. Topography/Slope map of the study area

Slope is a very important factor for land suitability analysis of rangeland. Rugged topography is one of the most important causes of poor livestock distribution on rangelands. The reluctance of livestock to use steep slopes is not entirely undesirable, since these areas are often fragile and valley bottoms can better withstand grazing. Livestock vary considerable in their willingness to use steep terrain. Large, heavy animals such as mature cattle or camels have difficulty in traversing steep, rocky slopes. Therefore, these animals make little use of slopes with more than a 10% gradient. Sheep and goats use these areas more readily because of their small size, greater agility, and surefootedness.

Slope map of the study area was generated from the mosaicked tiles of the downloaded SRTM DEM in ArcGIS. The state boundary vector layer was used to mask the mosaicked SRTM, then slope map of the study area was produced in Arc GIS after filling the DEM.

2.5.2. Water resources distribution map

Accessibility of water available is prime factor for the growth and wellbeing of livestock and plant. Water is second to oxygen in importance to sustain livestock life, it is require for growth, regulation of body temperature, lactation, digestion, metabolism, excretion and hydrolysis of nutrients among other functions. Suitable places for grazing land should not be far away from water sources such as lakes, dams, streams, rivers, and ponds. This is also important for the growth of forage. Animals should therefore have easy access to water for their survival. Water sources dataset was imported into ArcGIS 10.5 as a data layer and was used to prepared water resources map of the study area.

2.5.3. Rainfall map

Rainfall affects food supply and foraging behavior, reproduction and livestock growth rate, it is therefore, very important in Ranch site selection. Rainfall is one of the factors affecting the growth of forage plants on grazing lands. It is important that there is enough rainfall for forage and grasses to grow properly and in abundance on grazing land. Food and Agricultural Organisation (FAO) recommended an annual rainfall of a range of 300 - 800mm suitable for growing forage on grazing reserves. Rainfall dataset was imported into ArcGIS 10.5 as a data layer and was used to prepared rainfall map of the study area.

2.5.4. Soil type

Livestock fulfil their feeding needs from plants, soil provides plants with all the necessary nutrients required. Its therefore provides foods for animal to grow. Temperature, rainfall and soil types determine where forages can be grown. Types of soils vary in many chemical and physical properties including water holding capacity, acidity, depth, and nutrient status. These properties can influence the suitability of a given soil's potential of forage production from the establishment, persistence to expected yields.

Soil type dataset was imported into ArcGIS 10.5 as a data layer and was used to prepared soil map of the study area.

2.5.5. Accessibility/Road network

Accessibility is an important factor for siting suitable ranch, because of the need to transport animals and their products from the ranch to markets within or outside the state. Construction of new road is always capital intensive project especially in rough terrain were a lots of hydrological structures are required to be constructed along with the road. Therefore, proximity of the proposed ranch to existing roads is a priority.

Road network dataset was imported into ArcGIS 10.5 as a data layer and was used to prepared road network map of the study area.

2.5.6. Protected area/Reserved in the study area.

Protected areas is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.

Protected areas or conservation areas are locations which receive protection because of their recognized natural, ecological or cultural values. There are several kinds of protected areas, which vary by level of protection depending on the enabling laws of each country or the regulations of the international organizations involved. Generally speaking though, protected areas are understood to be those in which human presence or at least the exploitation of natural resources (e.g. firewood, non-timber forest products, water,) is limited. Protected areas are implemented for biodiversity conservation, often providing habitat and protection from hunting for threatened and endangered species. Protection helps maintain ecological processes that cannot survive in most intensely managed landscapes and seascapes.

World Database on Protected Areas (WDPA) data was used to extract the protected area in this study. This data included all the shape and attribute files for designated nationally protected areas and areas defined under international conventions and agreements. WDPA dataset was imported into ArcGIS 10.5 as a data layer and was used to prepare protected area map of the study area.

2.6. Standardization and scaling of Criteria (Factors and Constraints)

Multi-criteria evaluation is the solving of a suitability problem using multiple layers of information. Each layer contributing to the solution is a criteria. However, these layers may be in different form and units. Therefore these spatial dataset need to be unify to assume same form, unit and has to be in a uniform scale then weight can be assign to each criteria depending of its important or otherwise in the decision processes.

This is a process of setting the relative importance of each criterion. Since the various factors chosen are in different units of measurements, for example: slope (in percent), distance maps (in meters). A pairwise comparison technique is typically used for rating and standardizing the ordinal values. A fuzzy set is essentially a set whose members may have degrees of membership between 0 and 1, as opposed to a classic binary or Boolean set in which each element must have either the value 0 or 1 as their membership degree.

2.7. Multicriteria Evaluation to identify areas suitable for cattle ranching in Bauchi State

A number of MCE techniques have been implemented in the GIS environment for tackling site selection problems. AHP, OWA, and the extension of AHP using OWA operators are some of the techniques used for solving the siting problems.

For continuous factors, a weighted linear combination is most commonly used. With a weighted linear combination, factors are combined by applying a weight to each followed by a summation of the results to yield a suitability map.

$$i = \sum wici \quad \text{.. .(1)}$$

Where;

S = Suitability,
w_i = Weight of factor,

C_i = Criterion score of factor As Stated by Eastman (2012), this procedure is not unfamiliar in GIS and has a form very similar to the nature of a regression equation. In cases Boolean constraints also apply, the procedure can be modified by multiplying the suitability calculated from the factors by the product of the constraints.

$$S = \sum wici \times \Pi cj \quad \text{................................ (2)}$$

Where;

c_j = Criterion score of the constraint j
Π = Product.

3. Results and discussion

The output of the objectives of this research are presented and discussed as are being highlighted in the methodology section.

3.1. Land Use Land Cover of the study area

Major classes of land use considered in this research are: Agricultural land, water body, bare sand, swamp area, forest, rivers/stream, and built-up areas as presented in figure 3 (Land use /land cover map of Bauchi state). Agricultural land cover about 91% of the total land mass of about 48140 square kilometer. This is a great advantage of having a required land for siting cattle ranch under various evaluation.

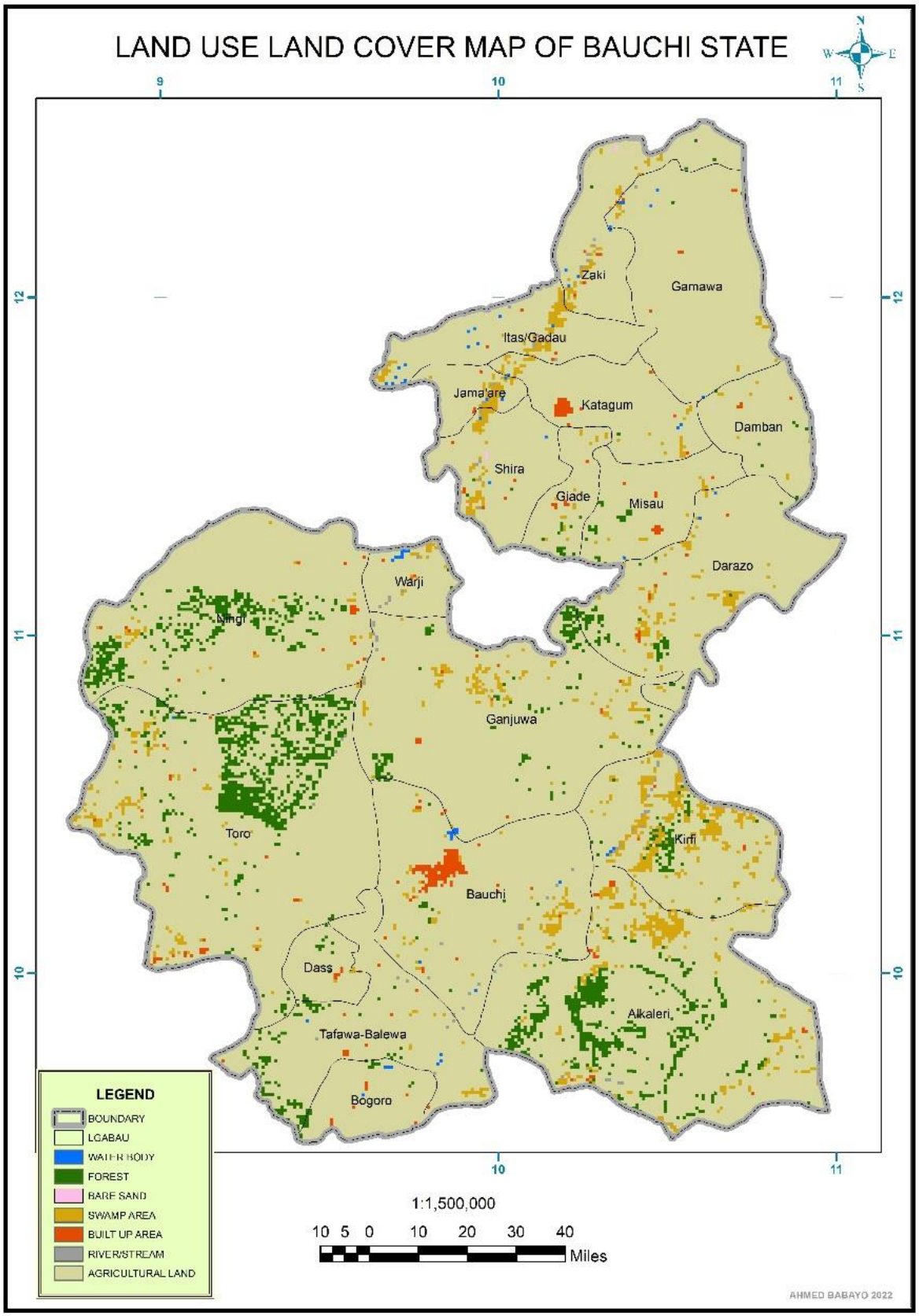

Figure 3 Land use /land cover map of Bauchi state

3.2. Topography/Slope map of the study area

Figure 4 is the aspect/slope map of the study area, it can be observed that the northern part of the state is relatively flat compare to the southern part which is characterizes with mountains and valleys. The topography of the study area steadily fall from the south to the north, this is because of the connectivity of the southern part of the state to the Plateau. The height of the topography above mean sea level ranges from about 200m (north) to 1700m (south).

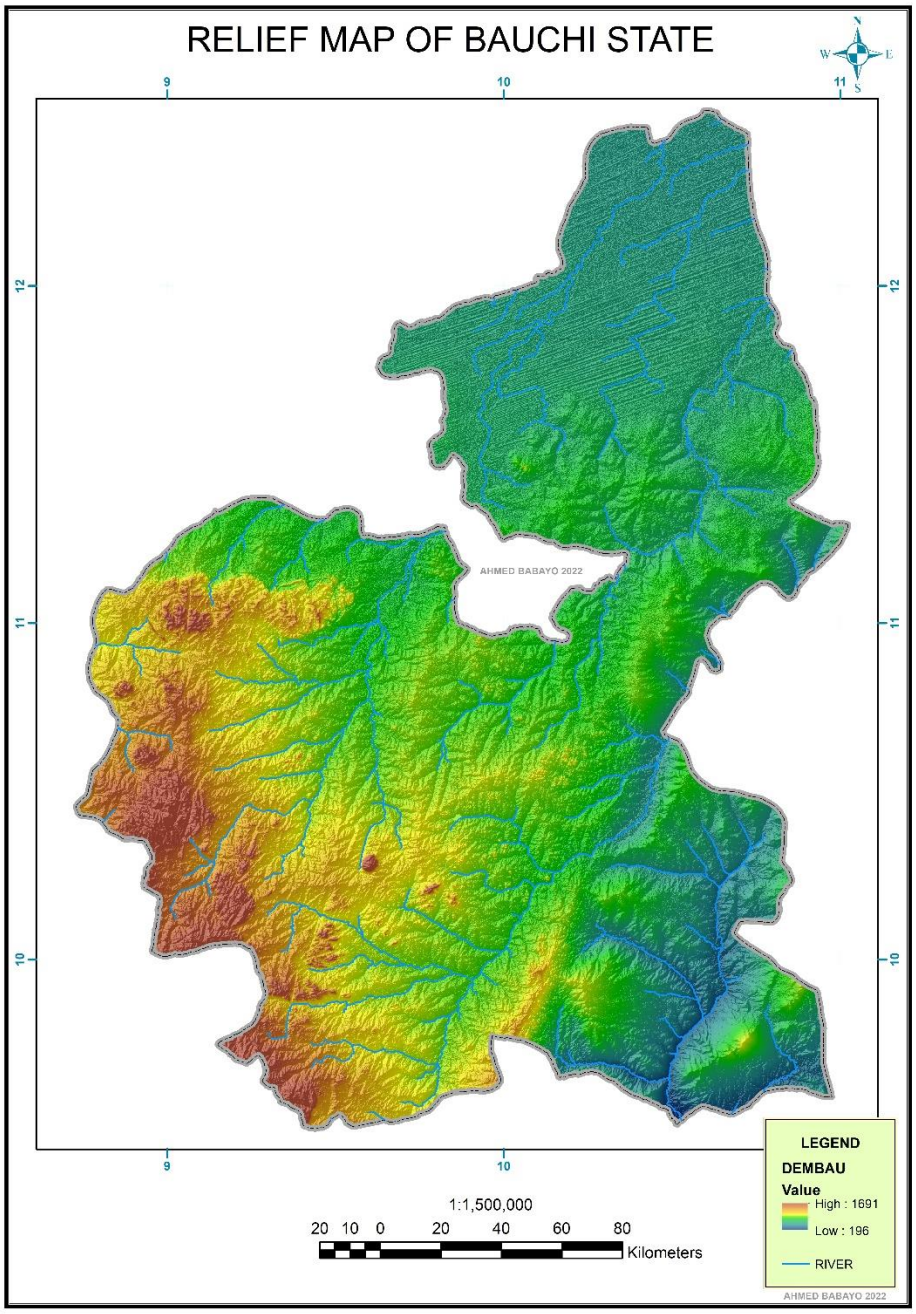

Figure 4 Aspect/slope map of the study area

3.3. Water resources distribution map

Accessibility of water available is a prime factor in determining suitable location for siting cattle ranch. As can be seen in figure 5. Bauchi state is endowed with abundance streams and rivers. Proximity to water source is a priority in this research.

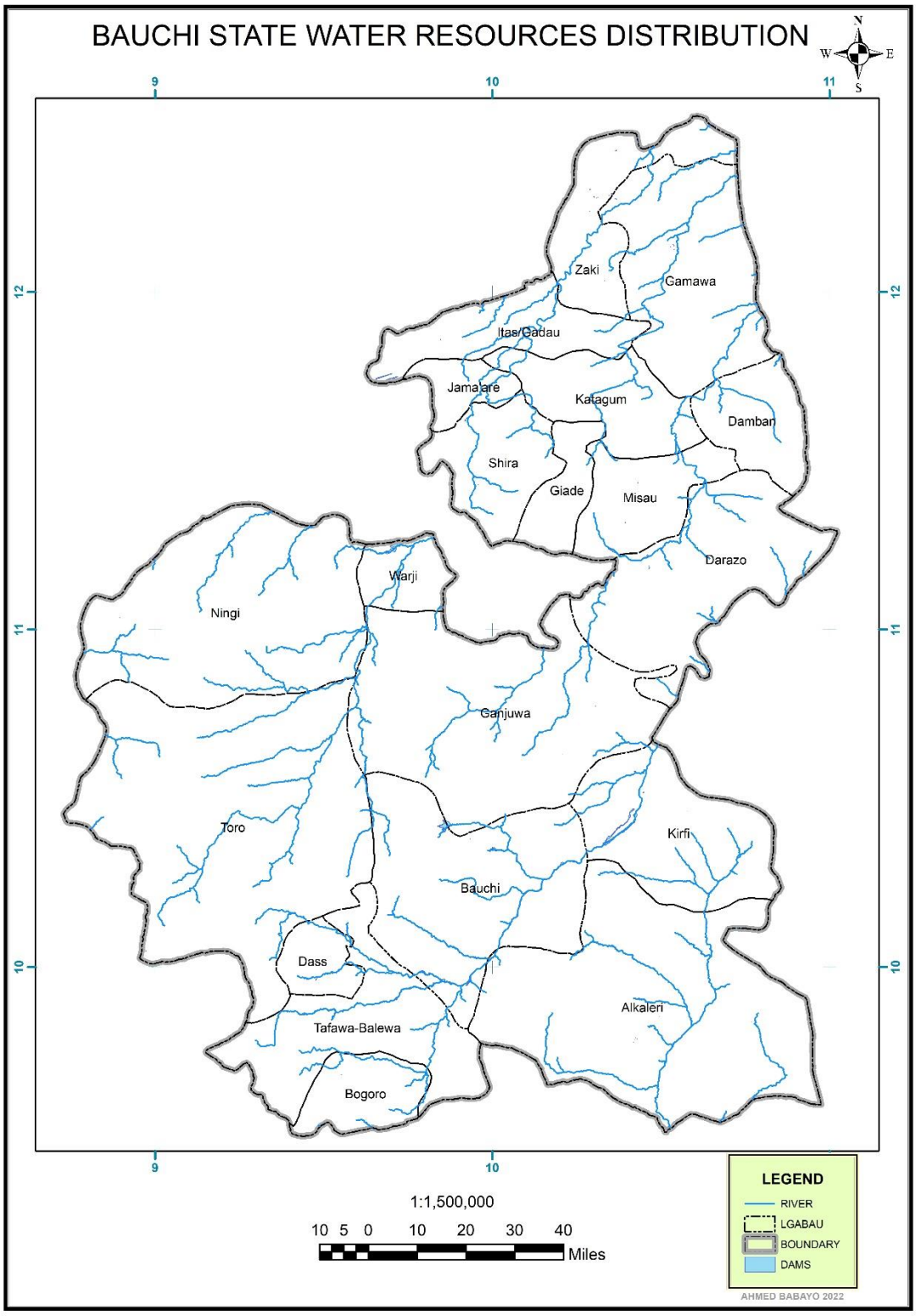

Figure 5 Water resources map

3.4. Rainfall map

Amount of Rainfall is the determining factor for the growth of forage and consequently food availability for the cattle. Figure 6 shows the rainfall distribution within the study area. It can be seen that the northern part of the state

experience lower amount of precipitation of about 700mm than the southern part which recorded an annual rainfall of about 1200mm. This is a great advantage to the southern part of the state.

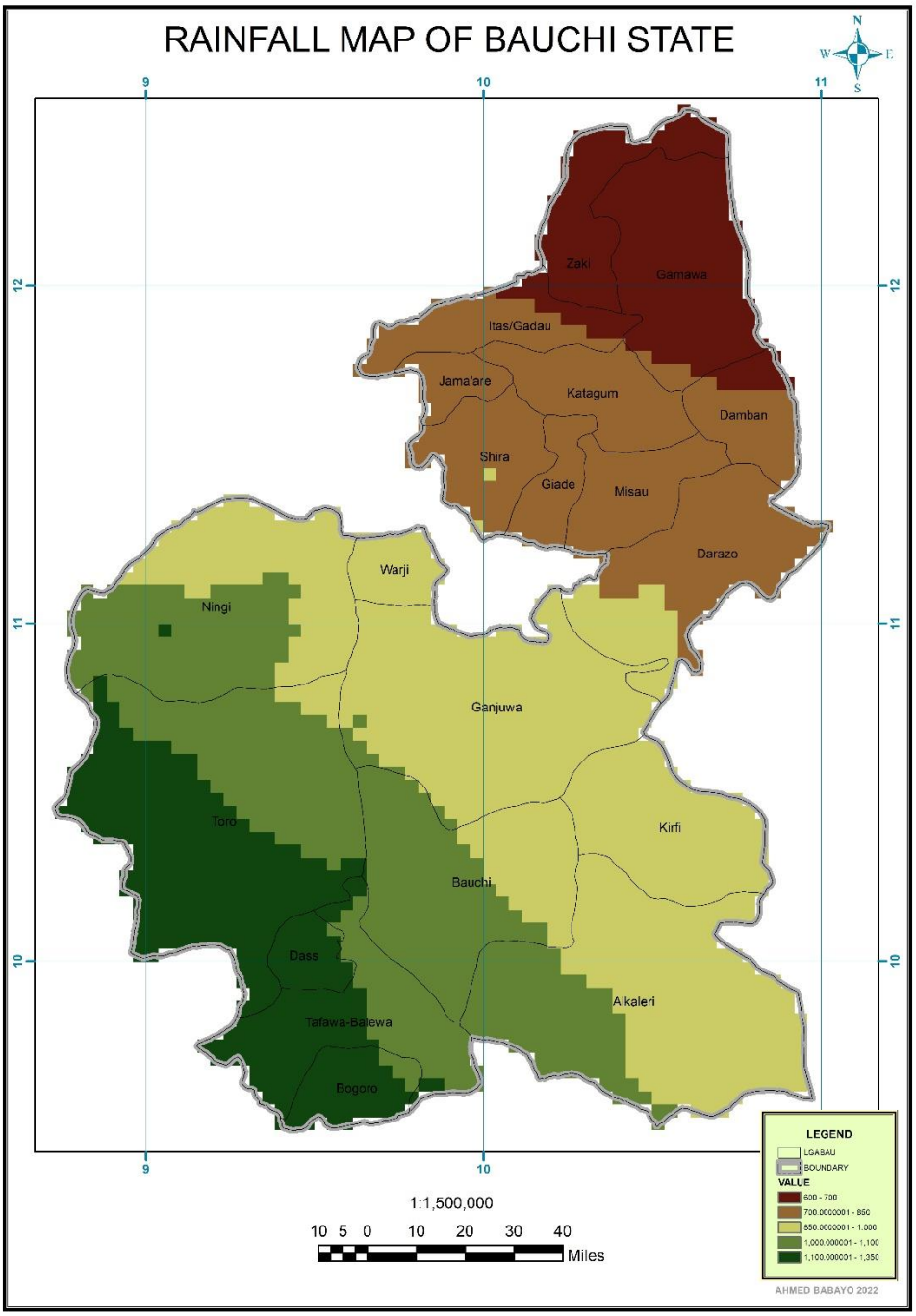

Figure 6 Rainfall Map of the study area

3.5. Soil type

Bauchi state is a geologically diverse state with different soil type patterns and topographic regions that allow for the distribution of different soil classifications range from shallow clay pan to deep silt loam soils suitable for forage growth. Figure 7 is the soil distribution map in Bauchi state.

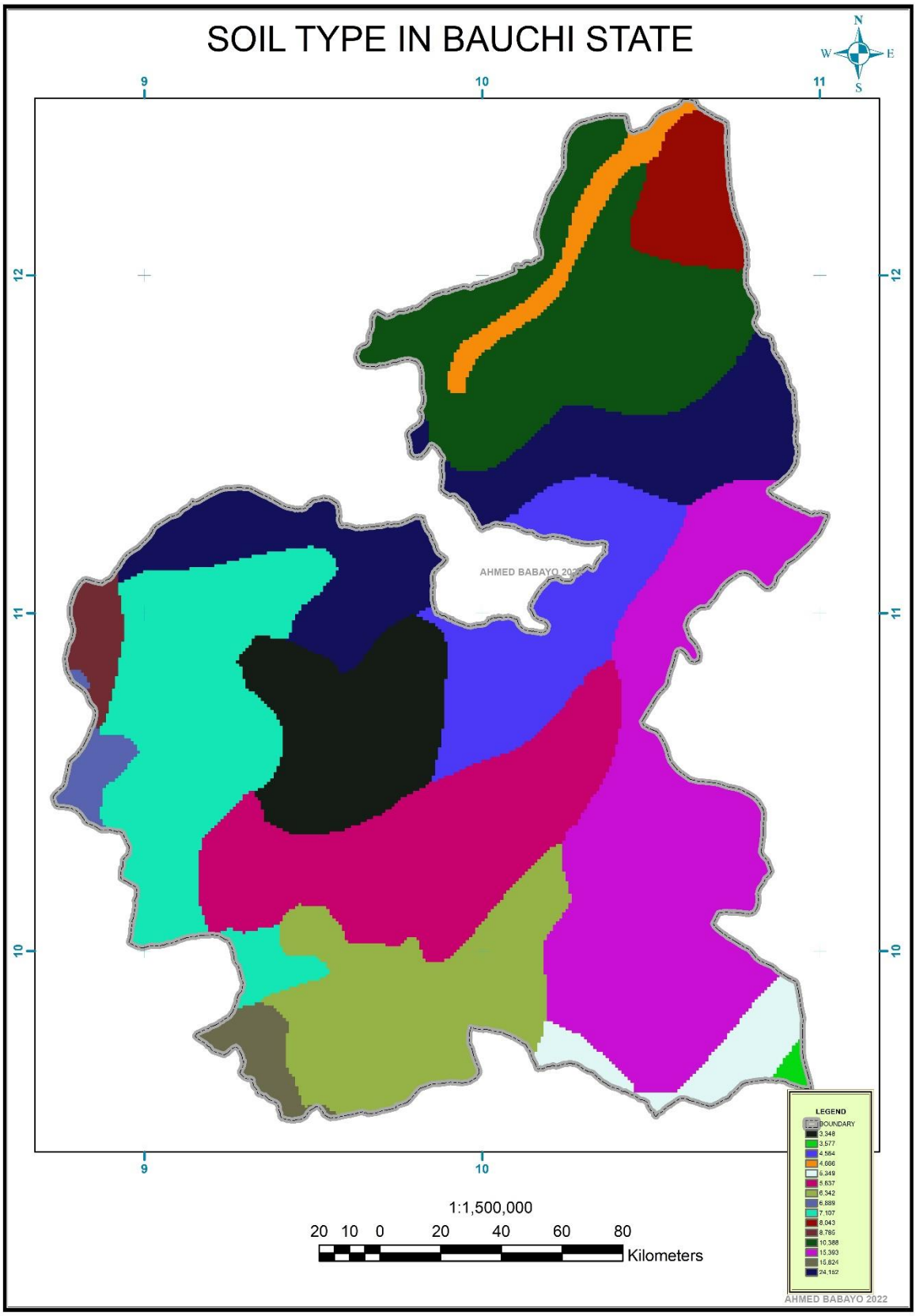

Figure 7 Soil map of the study area

3.6. Accessibility/Road network

Proximity to major roads is one of the important factor considered. Normally major roads leads to major market which facilitates movement of livestock and other daily requirement to and fro the ranch. Figure 8 shows the road network in the study area.

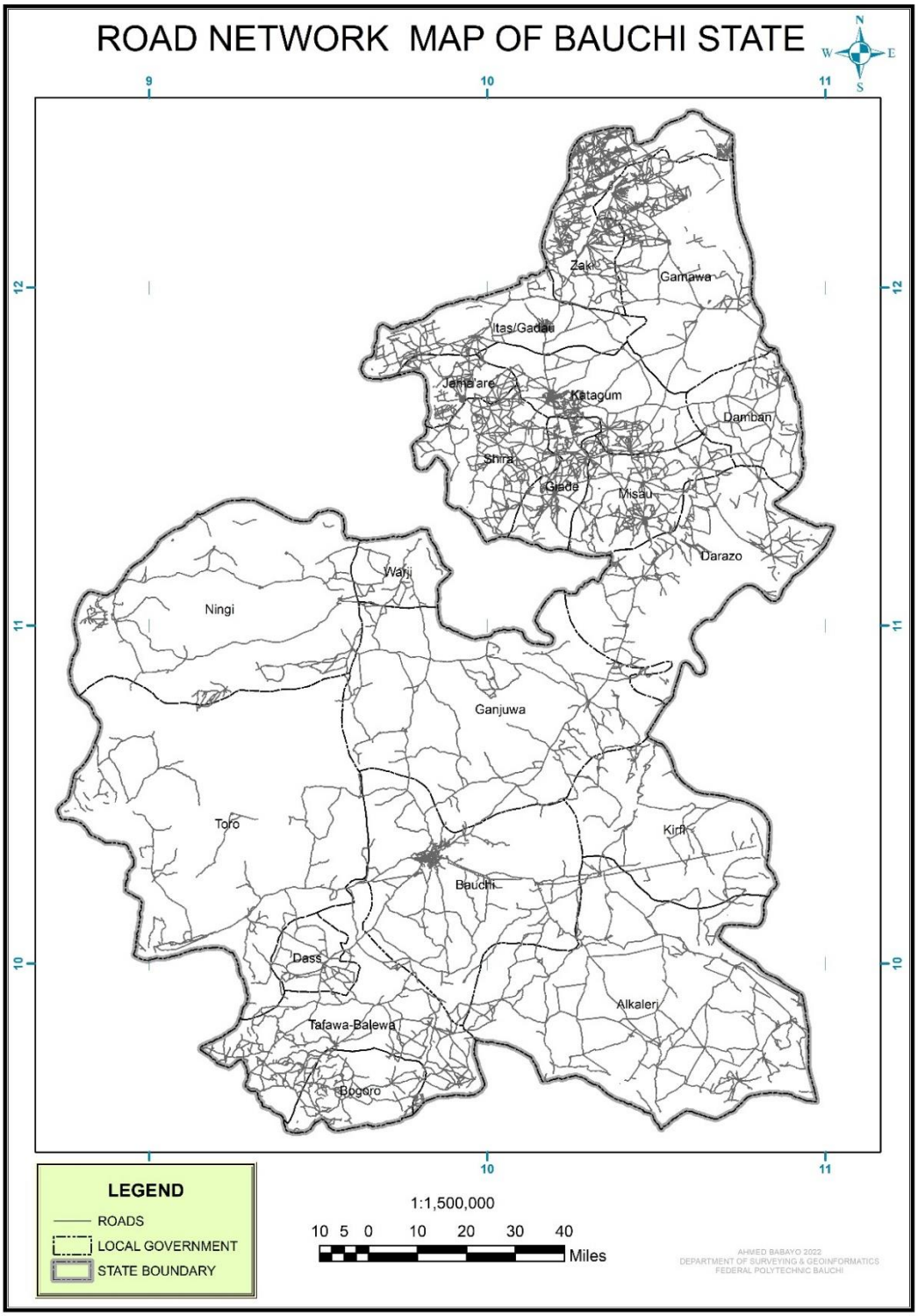

Figure 8 Road network in the study area

3.7. Protected area/Reserved in the study area

There are about 61 reserved areas in Bauchi state out of which 58 are forest reserved while 3 are game reserved. Yankari game reserve, Lame-Bura game reserve, and Baturiya wetland are the only protected areas that are considered avoidable in this research. Figure 9 shows the distribution of reserved areas in Bauchi state.

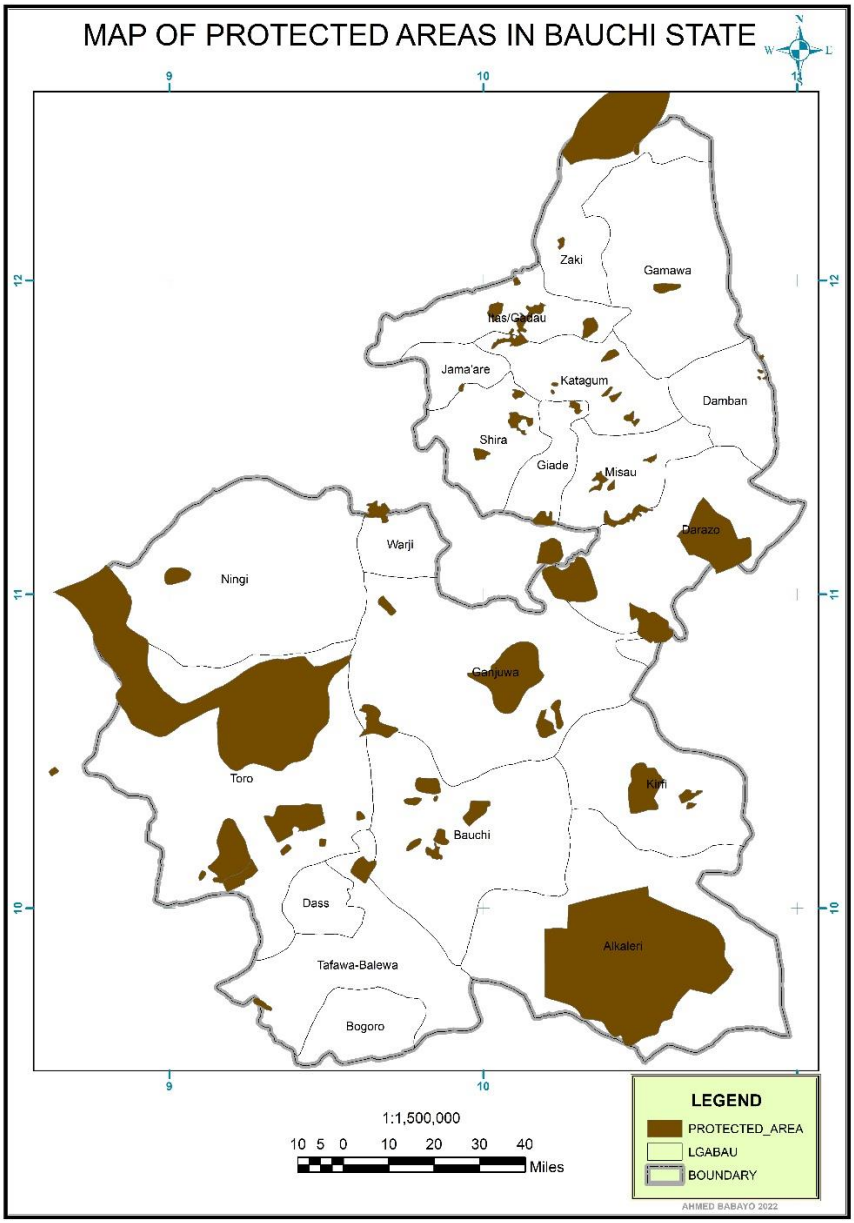

Figure 9 Reserved/protected areas in Bauchi state

3.8. Suitability map for siting cattle ranch in Bauchi State

Result from MCE shows about 41% of the total land mass in Bauchi state is suitable for siting cattle ranch. Although this is not a continuous extent however, there is a continuous extent of about 4914kmsq across Ningi, Toro, Tafawa Balewa, and part of Bogoro local government that shows to be highly suitable for siting cattle ranch. On the other hand 33% of the land shows to be unsuitable. While the remaining 26% is moderately suitable. This is presented in details in Table 2, while figure 10 shows the spatial distribution of the findings.

Table 2 MCE Result

FINDING	AREA (SQKM)	%
H-SUITABLE	10351	21
SUITABLE	9465	20
M-SUITABLE	12562	26
UNSUITABLE	7985	17
H UNSUITABLE	7805	16
TOTAL	28168	100

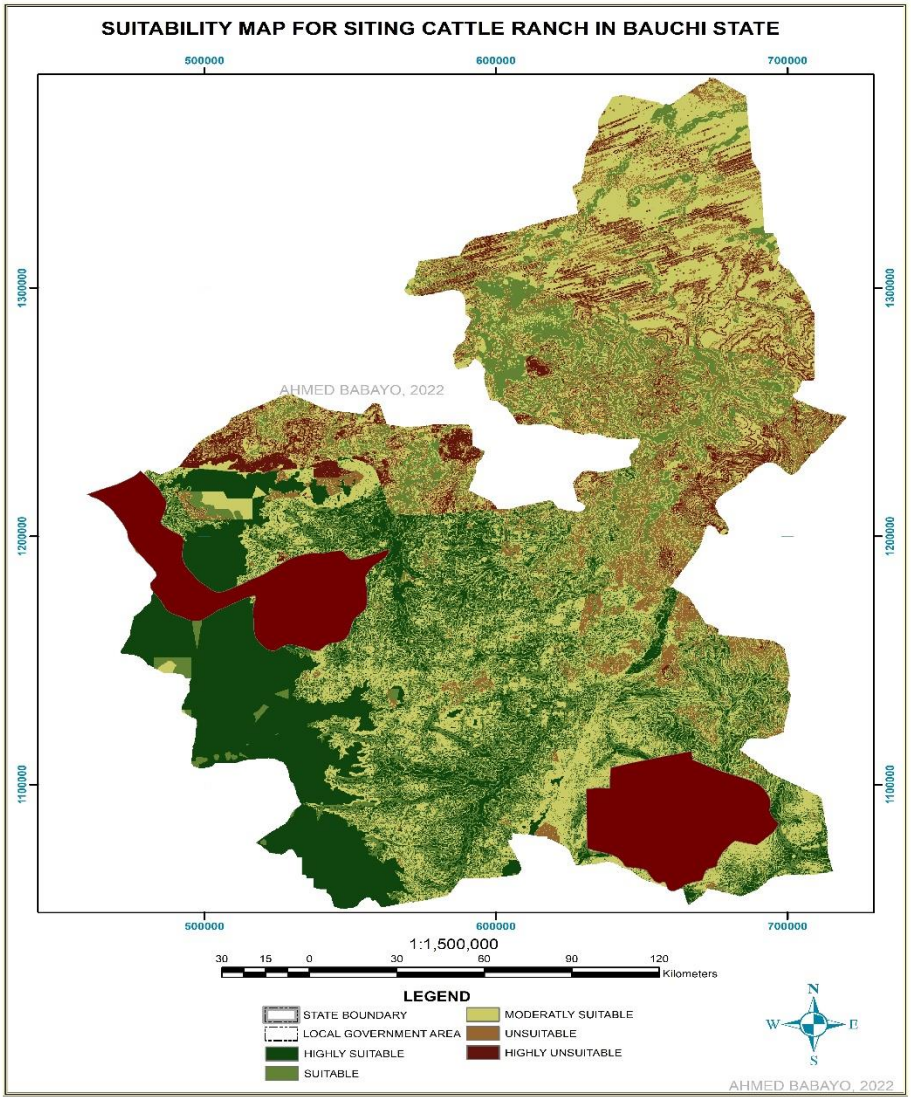

Figure 10 Suitability Map

4. Conclusion

Creation of ranches across states which has been considered as a panacea to farmers versus herder's conflict must be implemented in such a sophisticated manner so as to ensure sustainability and functionality. It is in the light of the foregoing that this research consider factors such as topographical, geological, hydrological, and climatological as well

as various other relevant factors that may have influence on the sustainability, functionality, and suitability of spatial location for siting of cattle ranch that has all the agronomics potential to ensure adequate forage and water availability. Averagely, major part of the state land is moderately suitable. However, most importantly more than ten thousand square kilometre was found to satisfy almost all the requirement needed for a successful and sustainable cattle ranch.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

Authors declare that there is no conflict of interest.

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