Application of Geographical Information System (GIS) and Analytical Hierarchical Process (AHP) in Suitability mapping of Girei LGA for Grazing Reserve

[1]Samuel, J., [2]Ezra, A. and [3]Ishaku, H.T.

[1]Physical Planning and Works Department, Federal University Wukari
[2]Department of Geography, Modibbo Adama University of Technology, Yola.
[3]Department of Urban and Regional Planning, Modibbo Adama University of Technology, Yola.
Email: andrewezra12@gmail.com

Abstract

The aim of this study is to produce a suitability map for grazing reserve in Girei LGA, Adamawa State. The data used for the study were; Base map of Girei LGA, settlements maps, Landsat 8 OLI and data on Gazette Routes and Grazing Areas in Girei LGA. Criteria such as; grassland, water bodies, road network, herders and non-herders settlements were used in the grazing reserve suitability mapping with the help of GIS and AHP. Findings of the study revealed that places like; Ngarilde, Daware, Gokra, Jarenga, Modire Jabilamba, Sangere Usman, Sangere Njida, Jera Bakari, Kofare, Hotolore, Wuro Basambo, Langere, Ardo Maguwa, and Hurriyandu which covered over fifty percent of the area are highly suitable grazing reserve in the LGA, while places such as Bajabure, Badarisa, Vunoklang, Labundo, Koh and Wuro Dole are not suitable for grazing reserve. The study concluded that increase in population and urbanization have taking over the existing grazing reserve thereby making some of the places not suitable for grazing reserve. The study recommended that planning authority should extend development control to all gazetted routes and grazing areas to avoid further encroachment, integration of cattle route and grazing areas as a guide for development control. The marking of grazing routes should be done in short distance not more than 500 meters in built-up areas.

Keywords: Analytical Hierarchical Process (AHP), Girei LGA, GIS, grazing Reserve and suitability mapping

Introduction

Pastoralism is in crisis globally as a result of man-made, natural constraints, internal and external influences. The trend at which human settlements are growing and spreading in the 21st century as a result of population growth and diversification in all human endeavors has made the physical spaces within developed and undeveloped communities highly competitive among fauna and flora. As such, the demand for pastoral facilities such as grazing reserves, grazing routes and water point, has become imperative leading to the lingering conflicts between pastoralists and farmers. This crisis is also exacerbated by the

increase in urbanization and rapid population growth which result in shrinking of pasture land and encroachment into cattle routes particularly during raining season.

In Nigeria, it is inevitable to talk about crisis in the country without making reference to farmers-pastoralist conflicts which occurred as a result of many factors. For example, Nzeshi (2013) documented that, the clashes between farmers-herders across the length and breadth of the country is caused by the struggle over land ownership and usage which could be traced to crop cultivation or rearing of animals. Similarly, Ofuoku and Isife (2009) presented that, the advancement of farming through irrigation and the increased decimation of pasture across the savannah has extended the scope of conflicts to the coastal zones which were more ecologically viable. Ajuwon (2004) also affirm that encroachment by both farmers and pastoralist is as a result of inadequate stock routes leading to water source, inadequate grazing reserves, blockage and reduction in size of cattle routes, land tenure and land use practices which lead to conflict between the two parties.

Girei Local Government Area (LGA) is an agrarian community like other places in Nigeria with majority of its population engaged in either crop cultivation or livestock farming such as cows, sheep and goats that requires vast expanse of open land for grazing. Recent studies in the LGA revealed that, struggle for common resources is one of the factors that degenerated into violent conflicts in the area between Fulani herders and local crop farmers. In addition, encroachments of traditional cattle routes and grazing reserves as a result of increased in population have drastically reduced the grazing space for the livestock to access pasture and water points which triggered crisis between Fulani herders and crop farmers (Mahdi, 2018; Ibrahim, Bakari & Aliyu, 2017). To affirm this, preliminary investigation revealed that land uses are not clearly defined at both micro and macro levels of development, buildings and other facilities encroached into all kinds of transportation routes and available open spaces, forcing cattle and other road users to compete for the only available road which in many occasions result to accident that claims lives and properties. It was also observed that, most of the livestock found within the study area and its environs are kept under traditional method of livestock practice (transhumance) which demands free movement of livestock from one point to another in search of pasture. It is against this background that this study is designed to produce a suitability map for grazing reserve in Girei LGA.

Description of Study Area

Girei Local Government Area is located at the central zone of Adamawa State, Nigeria. The study area lies on latitude 9° 15′N to latitude 9° 36′N and longitude 12°15′E to longitude 12°45′E with total land area of about 1,848 km^2. It lies along the Benue River with Fulani as dominant tribe. However, substantial numbers of minority ethnic group such as Bwatiye dwell in villages like Gereng, Tambo and Koh within Girei local government

area. The primary occupation of the people in the area is both wet and dry season farming with reasonable number involve in livestock rearing. Figure 1 showed the study area.

The study area lies within the Guinea Savanna vegetation zone of Nigeria. It is characterized by grassland with few trees and many shrubs with wide varieties which includes Tridax Procumbens, Amaranthus Spinosup, Gamba grass, Bahama grass, Andropogon, hyperthermia, Penincum species with other stem grasses. Some of the vegetation cover has been altered by human activities, most especially those around the settlements which are now either removed for construction or replace with exotic species such as neem and eucalyptus trees that are planted for the purpose of landscape (Akosim, 1999).

The study area is found within the tropical climate and has a mean monthly sunshine hour of about 220 from January to April, this decrease to mean value of 207 hours between May to September due to cloudiness, the mean sunshine hour increases again to about 255 from the period between October and December. The mean annual Temperatures is 27.8^{o}C but it increases from January to April due to increase receipt of solar radiation. The high temperature is usually experienced before the inception of the harmattan dust around December. Rainy season in the study area start from May and end in October with a mean annual rainfall of 919mm (Adebayo, 1999).

The dominant soil types found in the study area include cambisol, luvissol and regosols which are found in different part of the study area. Cambisol is the most widely sprayed soil type and are deep poorly drained with medium tenure and have sandy loamy, silt loamy or loamy sand surface horizon and lower horizon are usually sandy Luvissols are moderately acid, and are shallow to moderately deep and well drained. They have gravel to loamy sandy surface horizon and the lower horizons are usually sandy. Regosols are coarse textured soils with moderate to low organic content. They are generally dark to grey, grayish brown in color with pH of 6.4. Regosols are generally loose extensively drained and intensively leached (Ray, 1999).

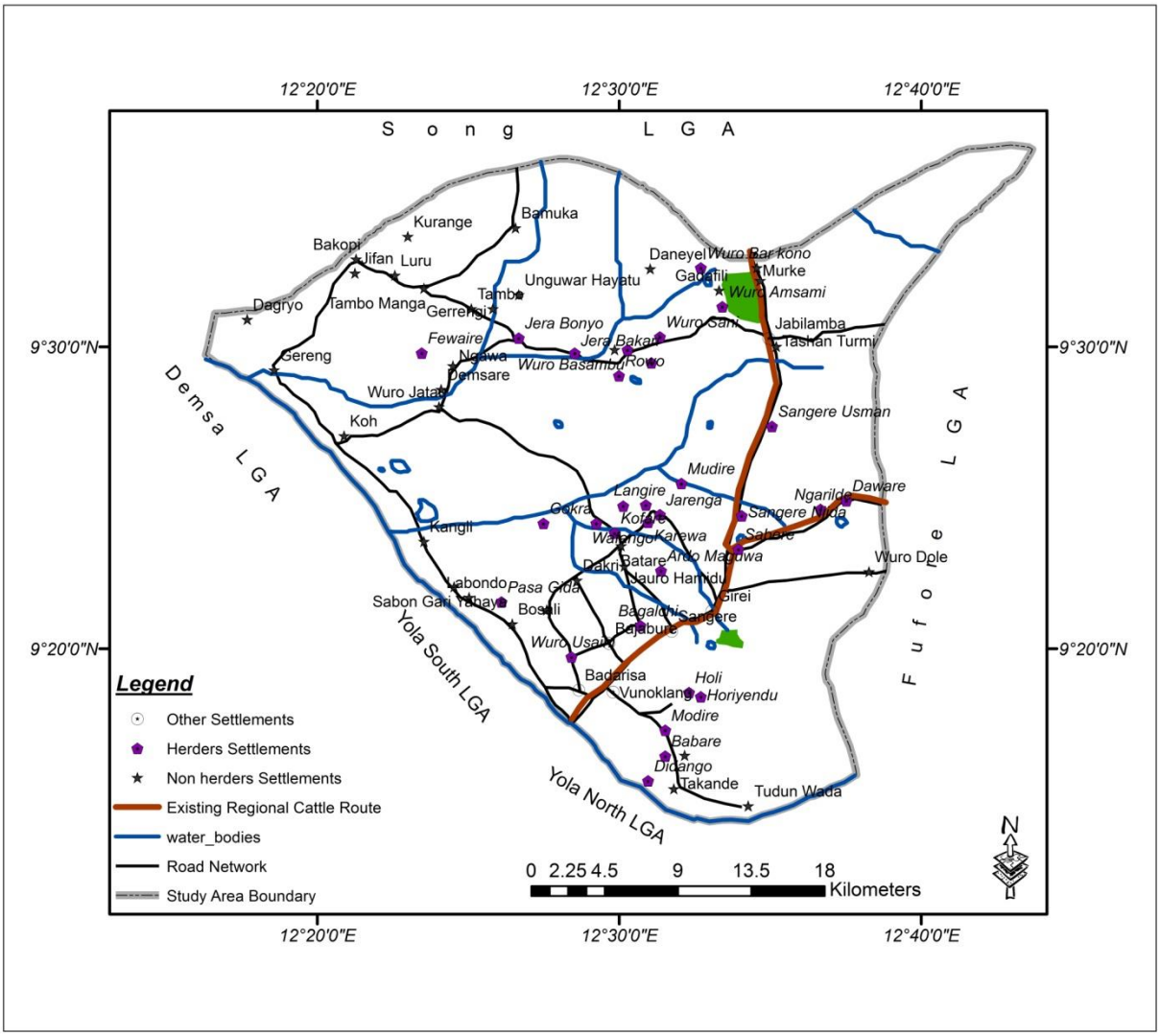

Figure 1: Map of Girei LGA

Source: Modified from Global Administrative Map (GADM) (2015)

Materials and Methods

The hardwires used in this study were: personal computer, GPS (Garmin 60) for taking coordinates, scanner for scanning map and digital camera for photographs, while the software used is Arc GIS 10.2 versions. The data used for this study were; base map of Girei LGA, settlements maps, landsat 8 OLI image and data on gazetted routes and grazing areas in Girei LGA.

Geo-referencing and digitizing were conducted on the secondary data that were used in Arc GIS. Data such as Girei map, road network map, settlements, among others were all geo-referenced and digitized to produce polygon and raster maps that were used in the suitability analysis. All point features generated from the field and their respective coordinate were also added with the help of the geo-reference and digitized maps. Grassland on the other hand, as one of the criteria was generated from Landsat 8 OLI through NDVI analysis.

Buffer zones were created based on the selected criteria used for the suitability analysis. The criteria included water bodies, road network, herders and non-herders' settlements in order to generate the suitability classes. Each buffer zone was generated according to the suitability scale were S1, S2, S3 and NS represent highly suitable, moderately suitable, marginally suitable and not suitable respectively.

Criteria for Suitability Analysis

The selection of suitable site for any land uses is influenced and determined by a number of factors. In this land suitability analysis, each criterion is represented by a separate map showing a suitability area based on it suitability for grazing reserve. These suitability maps were then rated according to the relative importance of contribution to grazing reserve. The selected criteria and their suitability classes were selected based on the consideration of literatures and data availability as presented in Table 1 and 2.

Table 1: Criteria for Land Suitability Mapping of Grazing Areas and Cattle Route

Criteria	Description
Proximity to grassland	Food for livestock is usually in abundance on grasslands and is paramount for establishing grazing area. This criterion is important because, the survival of livestock depends on availability of grasses or forage for consumption, as such; the grazing areas must be sited on grasslands or not far away from grasslands and forests as well.
Proximity to none herders communities	These are areas with predominantly farmers while the built up areas are mostly populated areas or settlements, if grazing areas are located close to such it will fuel the lingering issues surrounding grazing. Grazing sites are usually in conflict with urban built up areas and farming communities, as such, there is need to consider this aspect as criteria in order to control the conflict between grazing land and none-herders' settlement.
Proximity to water sources	The proximity to water source is an indispensable parameter for the siting of grazing areas. All animals require drinking water to be available at some time. Places with sources of water are suitable for grazing land, in addition such places are liable to grow better pasture than other parts. Source of water

	such as river, streams, lakes and dams attract herders from other places.
Proximity to herders' settlements	These are areas with predominantly cattle keepers who need grazing areas more.
Proximity to roads	Road is very important criterion in this site suitability mapping because of the need to transport animals and their products from the reserves to other places especially within settlements that are not pastorally inclined. Creation of routes for cattle within built up areas is very difficult therefore, this criterion was selected as environmental factor use for locating the grazing reserves closer to existing roads.

Source: Adapted and modified from (Lemmessa, 2011 & Abule, 2009)

Table 2: Suitability rating of each evaluated criteria used

Factors	Suitability Classification			
	S1	S2	S3	S4
Proximity to grassland	0 – 0.3	0.3 – 0.5	0.5 – 0.7	≤ -1
Proximity to none herders settlement (Km)	≥ 6	4 – 6	2 – 4	0 – 2
Proximity to water source (Km)	0 – 0.5	0.5 – 1	1 – 2	≥ 2
Proximity to herders' settlements (Km)	0 – 2	2 – 4	4 – 6	≥ 6
Proximity to roads (Km)	0 – 2	2 – 4	4 – 6	≥ 6

Source: Adapted and modified from (Lemmessa, 2011 & Abule, 2009)

Assessing the Criteria Weights Through Analytical Hierarchy Process (AHP)

AHP was used to calculate the weight for each criterion as well as consistency of Pair-wise Comparison. The purpose of weighting in this land suitability analysis is to express the importance or preference of each factor relative to other factor. In pair-wise comparison matrix, criterion was compared with one another in terms of their relative importance. Normalization was conducted from the pair-wise matrix in order to obtain the weight of each criterion used in the analysis.

In AHP application, it is important that the weights derived from a pair-wise comparison matrix are consistent. Therefore, one of the strengths of AHP is that it allows for consistent relationships while, at the same time, provides a Consistency Ratio (CR) as an indicator of the degree of consistency or inconsistency (Mu & Pereyra-Rojas, 2017). In developing the weights, each factor's importance was compared with another factor at a time and the rating was entered into the pair-wise comparison matrix according to the AHP 1-9 points continuous rating scale (Saaty, 2012).

In calculating the CR value, if the $CR \leq 0.10$, it means that the pair-wise comparison matrix has an acceptable consistency and that the weight values calculated are valid and can be

utilized, but if the CR > 0.10 it means that the pair-wise comparisons are lacking consistency, as such, there is a need to repeat the PCM (Saaty, 1977). CR was calculated with the help of consistency index (CI) as presented in Table 3.

$CR = {}^{CI}/_{RI}$

Where CI = consistency index and RI = Random index (Table 3.2).

Consistency index, on the other hand, is calculated as; $CI = (\lambda\text{-}n)/(n-1)$

Where Lambda (λ) is the maximum Eigen value and n is numbers of criteria in PCM

Table 3: Random Index (RI)

Order matrix	1	2	3	4	5	6	7	8	9	10
RI	0.0	0.0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty (2012)

Results of the Findings

Table 4 and 5 displayed the AHP results conducted on the selected criteria for grazing reserved. Based on the results obtained, it is clear that proximity to grassland has the highest percentage weight of 41.25% which revealed that, proximity to grassland has high influence on the suitability map for grazing reserved. Non herders' settlement on the other hand has 27.05% while proximity to road network has 8.63%. Herders' settlement as the last criterion has the least weight of 3.74%. The result also showed a consistency ratio of 0.019771 which revealed that there is a consistency in the pair-wise comparison matrix.

In other to produce the suitability map for grazing reserve, suitability map for each of the five criteria were produced as shown in Figure 2. All the selected criteria were overlaid using weighted overlay in spatial analysis tool of Arc GIS. The criteria were weighted based on the AHP result obtained.

Table 4: Pair-Wise Comparison Matrix (PCM) of the selected Criteria

Factors	Grassland	Non Herders Settlements	Water Bodies	Road Network	Herders Settlements
Grassland	1.0000	2.0000	2.0000	5.0000	9.0000
Non Herders Settlements	0.5000	1.0000	2.0000	3.0000	7.0000
Water Bodies	0.5000	0.5000	1.0000	3.0000	5.0000
Road Network	0.2000	0.3333	0.3333	1.0000	3.0000
Herders Settlements	0.1111	0.1429	0.2000	0.3333	1.0000
Total	2.3111	3.9762	5.5333	12.3333	25.0000

Source: Authors Analysis (2019)

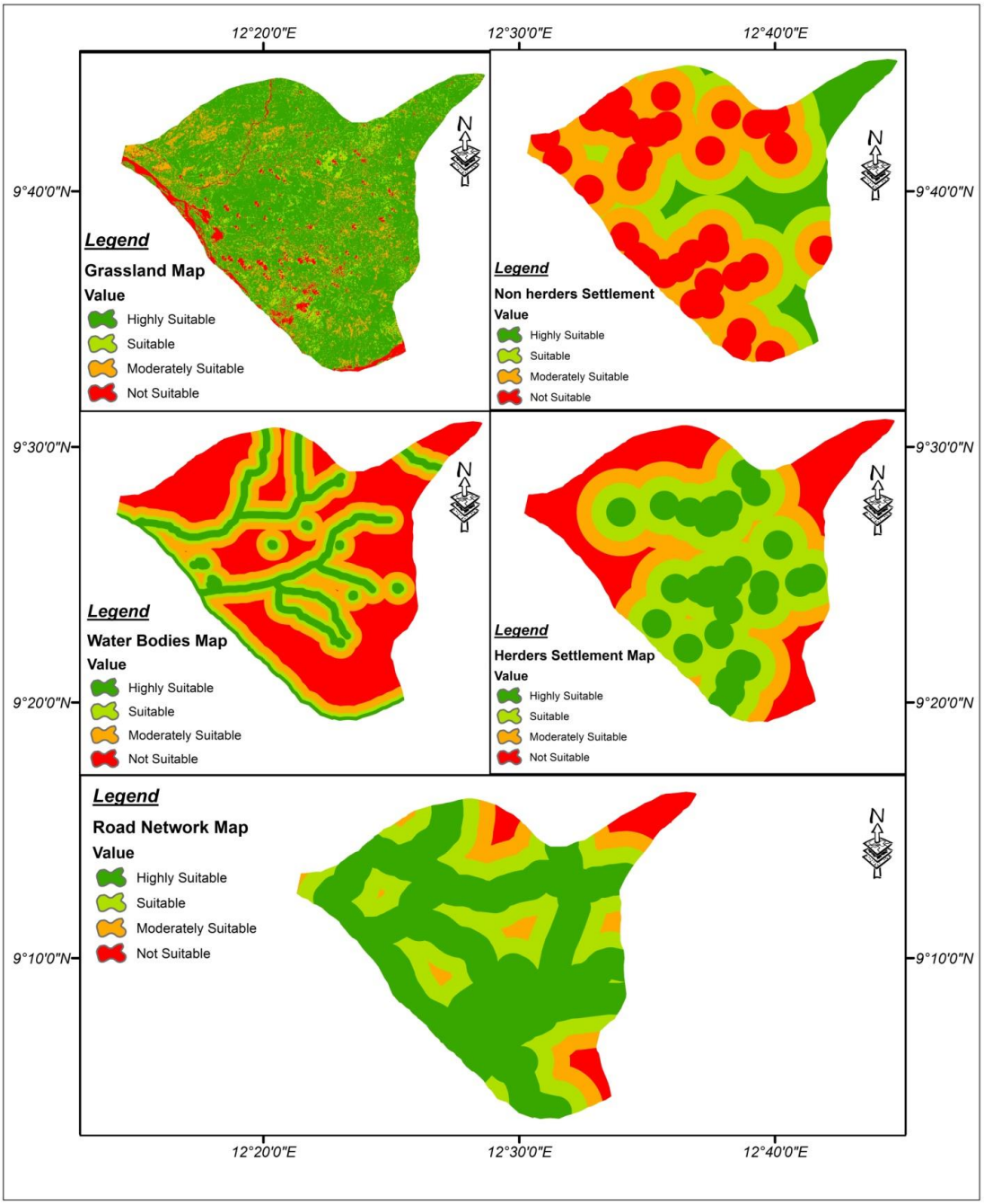

Figure 2: Suitability map of the selected Criteria

Source: Authors Data Analysis 2019

Table 5: Normalization of the selected Criteria

	Grassland	Non Herders Settlements	Water Bodies	Road Network	Herders Settlements	Weight	Weight (%)
Grassland	0.433	0.503	0.361	0.405	0.360	0.413	41.25
Non Herders Settlements	0.216	0.251	0.361	0.243	0.280	0.271	27.05
Water Bodies	0.216	0.126	0.181	0.243	0.200	0.193	19.32
Road Network	0.087	0.084	0.060	0.081	0.120	0.086	8.63
Herders Settlements	0.048	0.036	0.036	0.027	0.040	0.037	3.74

CI= 0.022143

CR= 0.019771

Source: Authors Analysis (2019)

Result of the suitability map for grazing reserve is presented in Figure 3 and the result revealed that, the highly suitable areas for grazing reserve include places such as; Ngarilde, Daware, Gokra, Jarenga and Modire which covered a total land area of 44.79km^2 (4.1%), while the suitable places for grazing reserve in the area cover places such as; Jabilamba, Sangere Usman, Sangere Njida, Jera Bakari, Kofare, Hotolore, Wuro Basambo, Langere, Ardo Maguwa, and Hurriyandu which has a total area of 763.55km^2 (70.6%). All the highly suitable places were identified based on the fact that, those places have sufficient grass cover which is essential for cattle feeding as a major determinant for locating grazing reserved in an area (Oladele, 2002). Similarly, the area is located far away from non-herders a settlement is also a major factor that lead to crisis between herders and crop farmers. This is based on the fact that cattle will not have the chance to intrude into crop farms since they are located far away from the crop farmers settlements. In the same vein, the highly suitable and suitable places for grazing reserved were identified to be places located closer to water bodies. This is based on the fact that herders move in search of pasture and water availability after feeding (Msuya, 2015). Finally, those places were suitable for grazing reserve because they have all the natural resources that cattle required for their feeding as also documented by (Mohammed, 2015).

The not suitable places on the other hand which include places such as Bajabure, Badarisa, Vunoklang, Labundo, Koh and Wuro Dole (total area of 10.71km^2 (1%)) were identified not suitable based on the fact that some of the essential requirement for cattle rearing are missing and some of the places with little resource have been taken over by population increase and urbanization which shrink the ecological space thereby creating eco-scarcity which lead to competition and desperate struggle for cattle to survive because the available grasses for grazing were converted to other land use. This is similar with the view of Okoli and Atelhe (2014) who reported that shrinking of ecological space and resorts creates an atmosphere of eco-scarcity which raises the stakes and premium on the available resources. The finding also agreed with the view of Abdullahi *et al* (2015) who also documented that,

as the need for more farmland arises due to increasing human population, the available "Kurmi" (Forest) and their connection "Burtali" (cattle route) continue to decrease and their carrying capacity is deteriorated. Figure 4 showed how cattle route were encroached by population growth and urbanization.

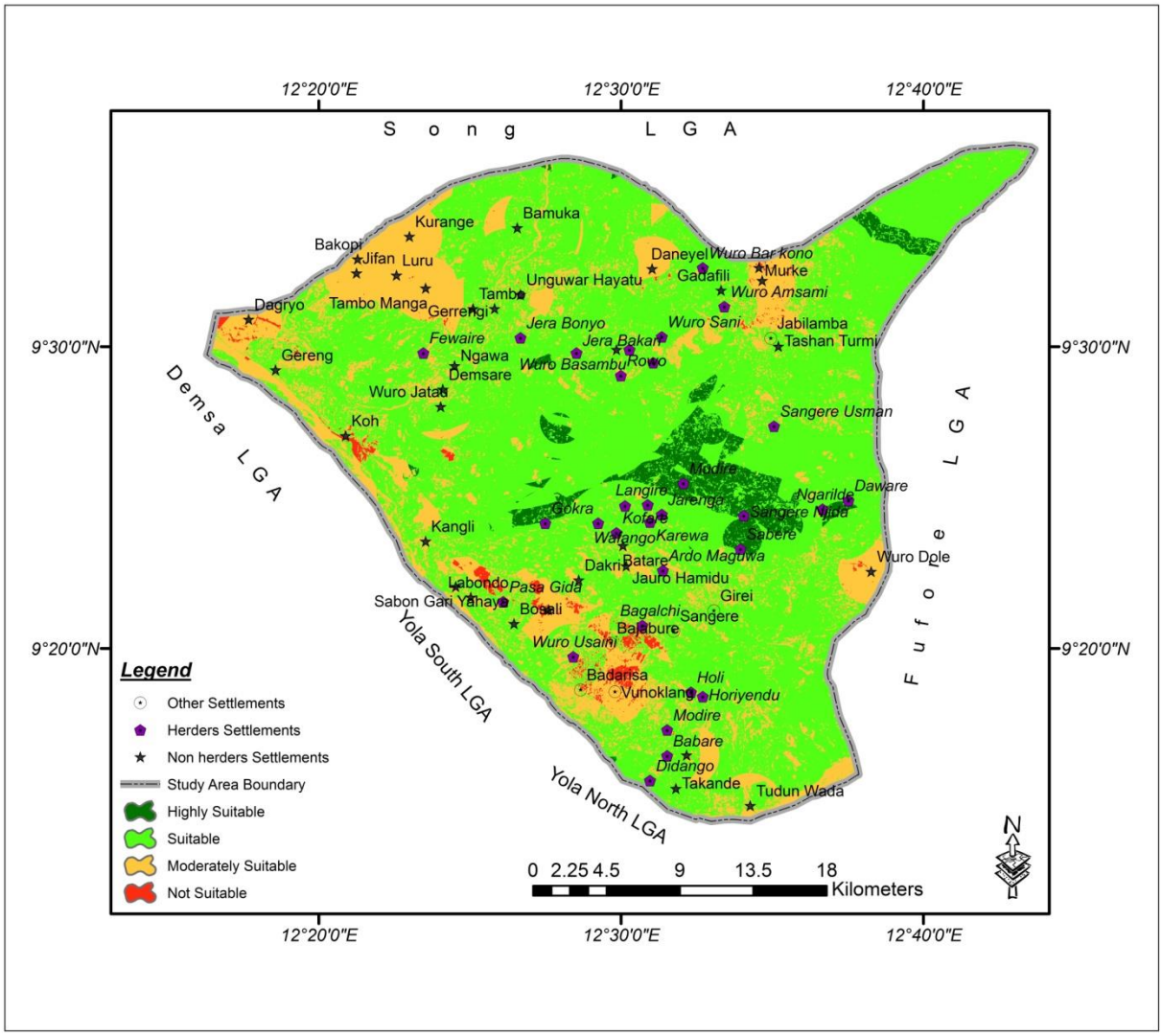

Figure 3: Suitability map for Grazing Reserve

Source: Authors Data Analysis 2019

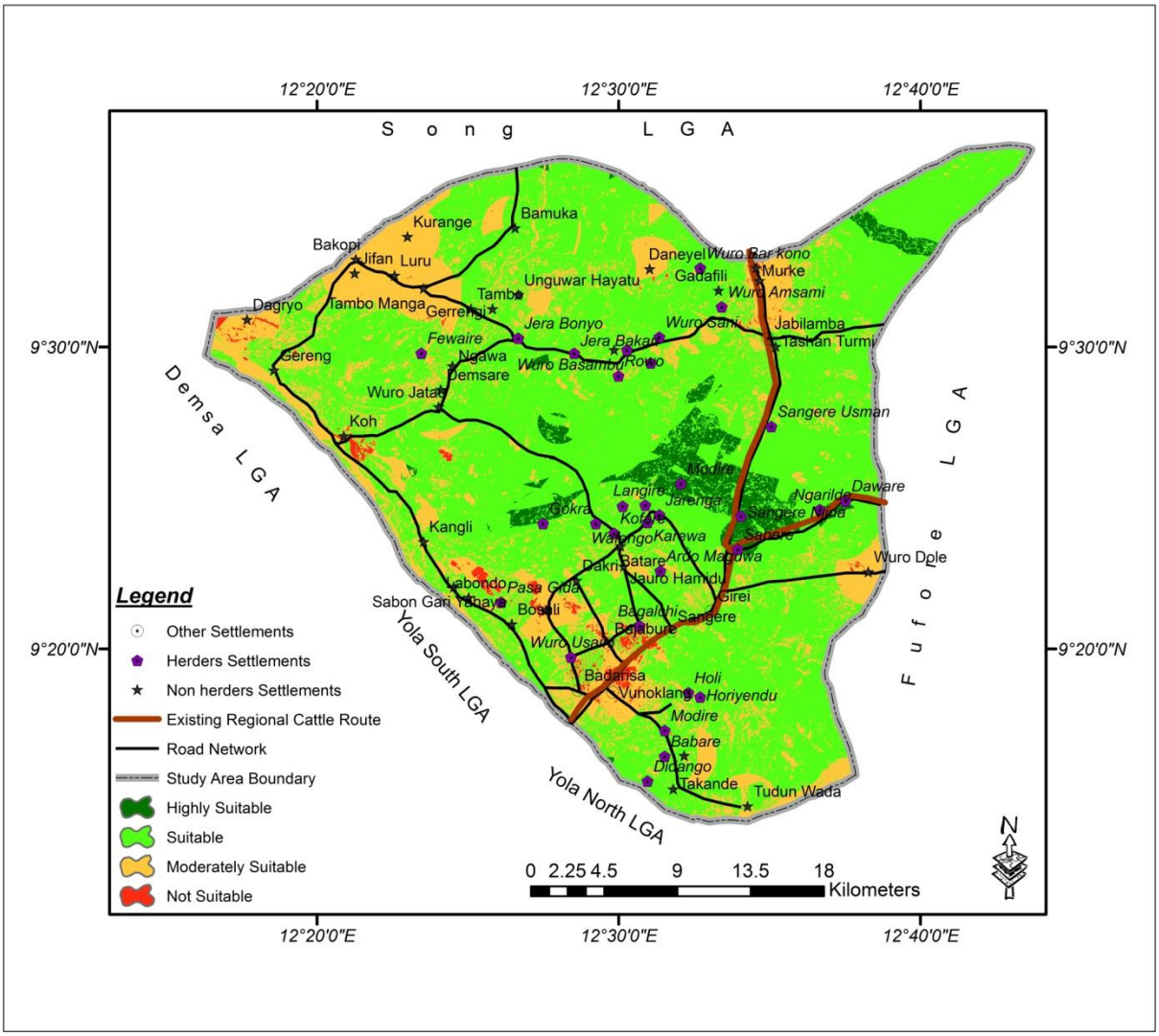

Figure 3: Suitability map for Grazing Reserve and Gazette cattle route

Source: Authors Data Analysis 2019

Planning Proposal

There are a numbers of cattle routes and grazing areas which spread across the length and breadth of the ten wards that constitute Gerei LGA with only few gazetted and established, though some of this routes and grazing areas are encroached or even completely blocked. The Following planning proposals were identified;

i. Buffer zone as a form of barrier between incompatible land use that enhance protection of specific areas. Buffer zone of 50m need to be created around

grazing areas to checkmate encroachment by farmers and other land uses into the grazing areas.

ii. Provision of cattle facilities such as animal crossing sign post should be designed to show cattle crossing point.

iii. There is a need for creation of alternative route to access grazing areas especially the non-gazette based on the land suitability analysis produced.

Conclusion

This study has examined the application of GIS and AHP in suitability mapping of Girei LGA for grazing area. It was observed that increase in population and urbanization have taking over the existing grazing reserve thereby making some of the places not suitable for grazing reserve. Based on the findings of this study, it was concluded that places like; Ngarilde, Daware, Gokra, Jarenga, Modire Jabilamba, Sangere Usman, sangere Njida, Jera Bakari, Kofare, Hotolore, Wuro Basambo, Langere, Ardo Maguwa, and Hurriyandu which covered over fifty percent of the area are highly suitable and suitable for grazing reserve in the LGA, while places such as Bajabure, Badarisa, Vunoklang, Labundo, Koh and Wuro Dole were not suitable for grazing reserve. Furthermore, it was concluded that, AHP is very important in suitability study because it provides a means in which criteria are rank based on their contribution to grazing reserve. This study was able to identify cattle route and grazing areas as current challenges that affect both urban and rural communities, it also establishes that cattle and grazing areas are integral land uses that need to be integrated into other land uses and preserved to ameliorate farming and grazing activities.

Recommendations

Based on findings of the study, the following recommendations have been made:

i. Government should conduct routine check on all gazetted routes and grazing areas in order to avoid further encroachment.
ii. Map of cattle routes and grazing areas should be provided at all planning authority offices to serve as a guide for development control.
iii. The marking of routes should be done in short distance not more than 500 meters in build-up areas.
iv. Supporting the exploitation of the resources and infrastructure available for the mutual benefit of crop farmers and pastoralists by not treating the grazing reserves as well as farmland, separation of the pastoralists and their livestock from farmers especially during wet season.
v. Restriction should be enforced to herders grazing around farmland and farmers around grazing areas and routes.
vi. The activities of traditional settlement such as farming, fishing and pastoralism communities should be preserved.

vii. Ranching method should be adopted by herders; open grazing in build-up communities should be discouraged.

viii. This study can be further extended to develop a model that can be used continually with additional criteria for greater efficiency of the geospatial method adopted for suitability mapping of grazing reserves and routes.

References

Abdullahi, U., Daneyel, H. & Aliyara, Y. (2015). Grazing Reserves and Pastoralism in Nigeria. *Vom Journal of Veterinary Science,* 10; 137 – 142

Abule, E. (2009). Rangeland Suitability Evaluation for Livestock Production in Laga Wata Laga- Sura, Dawa and Rift Valley Sub-basins of the Borana Zone of 133 Oromia, Southern Ethiopia. *Oromia Water Works Design and Supervision Enterprise.* (Unpublished report). Addis Ababa.

Adebayo, A.A (1999). Climate 1: Sunshine, Temperature, Evaporation and Relative Humidity. In Adebayo, A.A. and Tukur, A.L. (eds). *Adamawa State in Maps.* Paraclete Publishers, Yola, Nigeria. Pp 20 – 24.

Ajuwon, S.S. (2004). Case study conflict in Fadama Communities in managing conflict in

community development session. National Fadama Office, Abuja. Pp.10-15.

Akosim, C. Tella, L. & Jatan, O. (1999). *Vegetation and forest resource.* In Adebayo, A.A. and Tukur, A.L. (eds). *Adamawa State in Maps.* Paraclete Publishers, Yola, Nigeria.

Ibrahim S. U., Bakari U.M. & Aliyu, A. (2017). Farmers and Herders conflicts in Girei Local Government Area, Adamawa state, Nigeria: Causes, Repercussions and Resolutions. *Scientific Papers Series Management, EconomicEngineering in Agriculture and Rural Development*. 17(1); 467-472

Lemmessa, F. (2011). *Rangeland Suitability Analysis for Livestock Production Using GIS*

and Remote Sensing: The Case of Yabello Woreda, Southern Ethiopia. (M.Sc. Thesis. School of Graduate Studies of Addis Ababa University, AAU, Ethiopia).

Mahdi, A.A. (2018). The Re-Occurring Farmer/Herder Conflict in Adamawa State: The Absence of Good Governance. *Asian Journal of Multidisciplinary Studies*, 6(8); 69-83.

Mohammed, B. (2015). Africa Regional Commission Bouslikhane Cross Border Movements of Animals and Animal Products and Their Relevance to the Epidemiology of animal Diseases in Africa.

Msuya, D. (2015). Pastoralism Beyond Ranching: A Farming System in Severe Stress in Semi-arid Tropics Especially in Africa. *Journal of Agriculture and Ecology Research International* 4(3);128-139.

Mu, E. and Pereyra-Rojas, M. (2017). *Practical Decision Making*; Understanding the Analytic

Hierarchy Process. SpringerBriefs in Operations Research, DOI 10.1007/978-3-319-33861-3_2

Nzeshi, O. (2013). Grazing Reserves Bill: *The Challenges Ahead*. *This Day Newspaper,*

August, 10.

Ofuoku, A. & Isife, B. (2009). Causes, Effects and Resolution of Farmers-Nomadic Cattle Herders Conflict in Delta State, Nigeria. *International Journal of Sociology and Anthropology.* 1(2); 047-054.

Oladele, O. (2002). *Fadama Development in Northern Nigeria and Cultivator-pastoralist Conflicts.* Agricultural Research and Extension Network. Newsletter.

Okoli, A.C. & Atelhe, G. (2014). *Nomads against Natives*: A Political Ecology of Herder/Farmer Conflicts in Nasarawa State, Nigeria. *American International Journal of Contemporary Research,* 4(2).

Ray, H.H. (1999). 'Soils and Erosions'. In Adebayo, A.A. & Tukur, A.L. (eds): *Adamawa State in Maps.* Paraclete Publishers. Yola. Nigeria. Pp. 27 – 31

Saaty, T.L. (1977). A scaling method for priorities in Hierarchical structure. *Journal of Mathematical psychology*. 15(3); 34-39

Saaty, T. L. (2012). *Decision Making for Leaders*; *The Analytical Hierarchy process for Decisions in a complex world.* Third Revised Edition. Pittsburgh: RWS Publications.