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SUITABILITY ANALYSIS OF FADAMA PRONE AREAS IN BIU PLATEAU REGION OF BORNO. AN AHP APPROACH

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Abstract: *The study was based on suitability analysis of fadama prone areas in Biu plateau region of Borno. an AHP approach. The aim is to determine Fadama suitability areas in Biu Plateau region using GIS and AHP method. The objectives were to: examined the fadama suitability areas through physiographics and to map out fadama suitable areas in the Biu plateau. The methods used were basically GIS and AHP. Five sources of data were utilized for this analysis. The first is high resolution 30m pixel digital elevation model (DEM) covering the entire study area comprising Biu, Bayo, Shani, Kwaya Kusar and Hawul local government areas of Borno state. The drainage Map was acquired from DEM using flow accumulation tool. The geology of the world was acquired in Map info format and uploaded into Global Mapper then converted to Geo-tiff format. The obtained hard copy soil map of Nigeria was scanned and geo-referenced. The result depicted that relief of the study area is classified into four classes viz upland the height covers between 595-952 meters, hills covers between the height of 446-595 meters, relatively flat plains covers the height of 315-446 meters and flat plains covers the height between 176-313 meters which is 21 percent of total area on Biu Plateau. Areas characterized by highly resistant or permeable subsoil material, low relief and dense vegetation tend to have low drainage density which is suitable for fadama area.* Mean annual rainfall in the region as found in this study ranges from 856.5 to 900.5 mm, with rainfall onset in April and cessation in October. *Luvisols and Fluvisols are soils that are frequently flooded and therefore suitable for fadama formation, woodland areas include: the riparian vegetation along the valleys of major rivers such as Ndivana which is suitable for fadama area. The low slope area mostly is attributed to fadama suitable areas around Shani, Bayo and Kwaya Kusar*

Keywords: *Suitability, Analysis, Fadama, AHP, Plateau, Region.*

Introduction

Analytical Hierarchy Process (AHP) and Pairwise Comparison Method (PCM) were employed to be the most widely accepted method and the most consistent MCDM method that helps to measure the weight of criteria with respect to another (Getachew and Solomon, 2015). Cheng Fu (2006) said AHP is a pairwise comparison procedure designed to capture relative judgements in a manner that that ensures consistency.In Nigeria, the term *"Fadama"* is a Hausa name, *"Walowol"* in Fulfulde, *"Akuro"* in Yoruba, *"Nke putra"* in Igbo, *"Kriswu"* in Kanuri, and *"Duw"*in Babur/ Bura meaning irrigable land usually found in low lying plains underlain by shallow aquifers and sometimes found along major river courses that are susceptible to flooding (Folayan, 2013, Musa and Adamu, 2016,

Kuza, Okwoche, and Age, 2018). Fadama an area that is waterlogged during raining season and retained moisture in the dry season or a low lying- lands relative to other areas adjacent to the river or stream which are characterized by water logged or flooded during the raining season (Datung, Fadare and Adereti 2017, Godwin and Choji, 2017). Collectively it could be defined as low laying lands that are subjected to seasonal flooding or water logging along the banks of streams or depressions. Fadama in addition to providing a source of water for livestock during dry season, fadama lands and by extension wetlands can therefore be described as some of the most critically important ecosystems in the world supporting millions of people (Abdulkadir,Mallam and Mohammed 2019) it also supports large and diverse resident or transient wildlife including herbivores, carnivores and migratory birds. Fadama lands are widely used for irrigation farming in the Northern parts of Nigeria. Summarily, Fadama could be defined as land that is liable to flooding and characterized by fertile soils which encourage both rainfed and irrigation farming at the river banks or streams.
The aim is to determine Fadama suitability areas in Biu Plateau region using GIS and AHP method. The objectives are to: examine the fadama suitability areas through physiography and to map out fadama suitable areas in the Biu plateau.

2.0 Study Area

The study area comprises five LGAs which include Bayo, Biu, Hawul, Kwaya Kusar and Shani all in the southern part of Borno State. Out of these five LGAs, Biu, Hawul and Kwaya Kusar are riparian to Biu Plateau. The study area lies between latitudes 10° 2´ 33.132˝ and 11° 5´ 53.98˝ N of the Equator and longitudes 11° 31´ 41.866˝ and 12° 35´ 45.585˝ E of the Greenwich Meridian. The region covers a total area of 8, 231.32 km^2. Biu Plateau occupies 2, 271.09 km^2 of the total land of the sudy area, that is about 27.59% of the study area. The area is bounded in the north western part by Yobe State, north east by Damboa LGA in Borno State, in the west by Yobe and Gombe State, in the south by Adamawa State and in the western part by Adamawa State, Askira/Uba and Chibok LGAs in Borno State (Fig. 1.1).

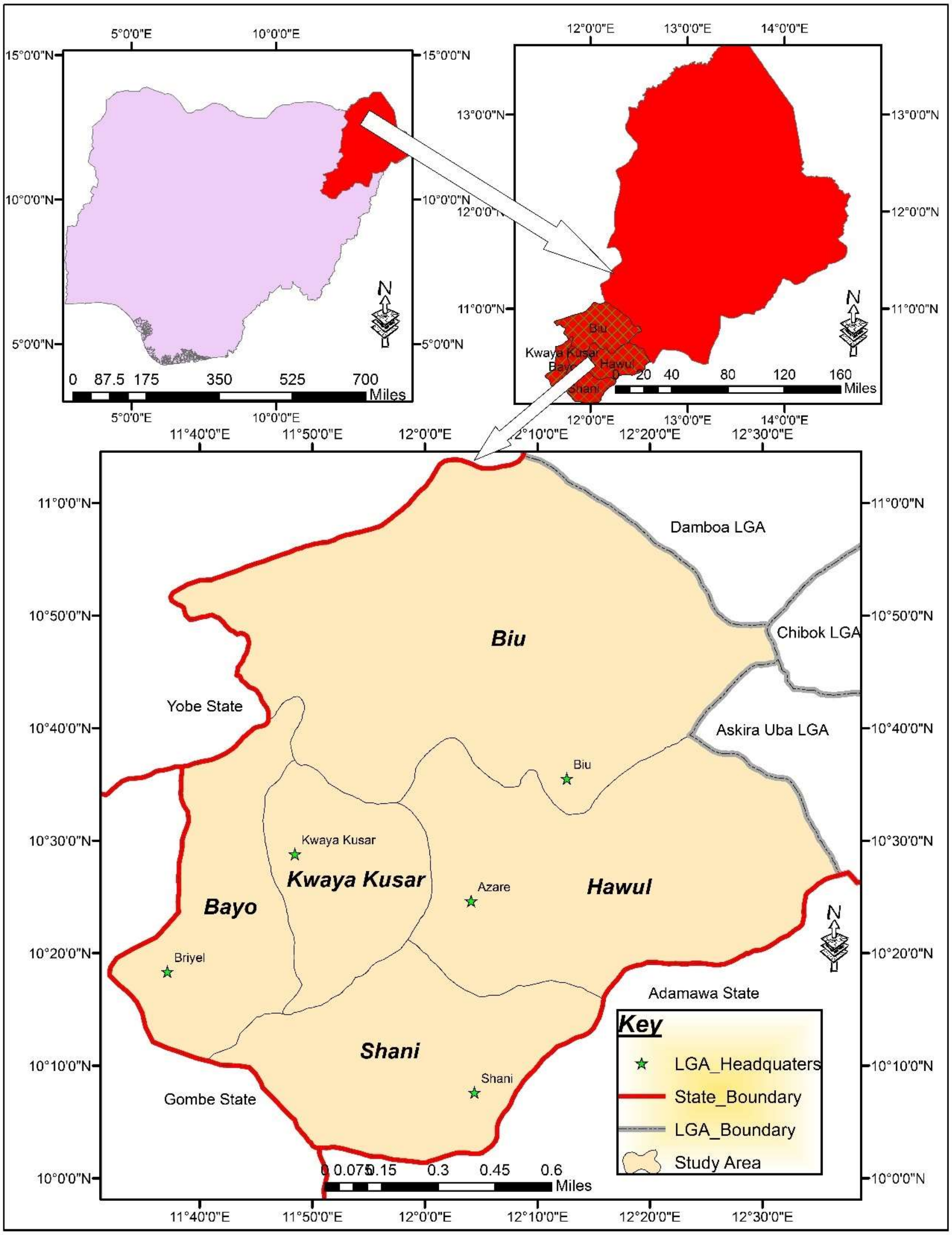

Fig 1.Borno state showing the study area

Methodology

The methodology focused largely on GIS and AHP approach which dealt with the physiography of fadama in the study area

Five sources of data were utilized for this analysis. The first is high resolution 30m pixel digital elevation model (DEM) covering the entire study area comprising Biu, Bayo, Shani, Kwaya Kusar and Hawul local government areas of Borno state. The next two data source utilized were two Landsat 8 imagery tiles in Geotiff format, captured on 19 March 2019 and the geology of the world in Mapinfo format respectively, from the United States Geological Survey (USGS) repository, soil map of Nigeria from Sonneveld B.G.J.S (1994) in hard copy was utilised. high-resolution (30 meters) satellite image of the entire study area obtained from Google Earth repository was used.

3.2 Generation and processing of the Digital Elevation Model (DEM)

Before application the DEM uploaded into the Arc GIS environment together with the boundary of the study area. The fill tool under the hydrological tool extension was used to fill sinks in the DEM. It was then clipped using the raster clip tool to acquire a new DEM for the study area only. The flow accumulation and flow direction tools in the hydrological tool extension of ArcGIS toolbox were then utilized to establish the direction of flow and watershed of the study area. From the same filled DEM the slope map was also established using the slope tool in the hydrological extension of Arc GIS toolbox.

3.3 Generation and processing drainage density

Drainage as factor play an important role in the mapping of Fadama. The drainage Map was acquired from DEM using flow accumulation tool. Kernel Density tool from Arc toolbox with geo-processing fill, flow accumulation, stream order and stream to features were used to generate river or drainage density and maps were clipped together.

3.4. Generation and processing the geologic units

The geology of the world was acquired in Map info format and uploaded into Global Mapper then converted to Geo-tiff format. This was further uploaded into Arc GIS and clipped with boundary of the study area. The raster to polygon tool was then utilized to vectorising the raster.

3.5 Generation and processing the soil map

The obtained hard copy soil map of Nigeria (FAO/UNESCO,1961) was scanned and geo-referenced. The study area boundary was then superimposed on it and then digitized. For faster digitization the snapping and trace tool in the editing tool extension of ArcGIS toolbox were highly utilized. The soil types were up to twelve but for the purpose of this study were converted into raster and reclassified based on the fadama .A new filed was then opened in the attribute table to enter the soil names with same soil areas appropriately merged.

3.6. Generation and processing of climatic data

The two climatic elements that were considered in this study because of their influence on fadama development. The two data were obtained from DivaGIS climatic data due to non-availability and unreliability of in-situ data. Two hundred and eighty-seven equidistant points were created which cover the entire study area. Extract points from each of the climatic data (maximum and minimum temperature and precipitation) was performed and the values of each of the points were extracted.

3.7 Generation and processing of vegetation

The vegetation cover of the study area was derived from Landsat 8 OLI (2021). Two image scenes with the following characteristics cover the study area. Landsat 8 OLI 08/03/2021 column 52 and 53 band 4 and 5 from both.The analyzed NDV indices was used to classify the area into four classes: surface waterbody, non-vegetated areas (built up areas, bare surface and bare rocks) grassland, shrubs and forest/woodlands which are the main vegetation and land cover types in the area. Bands 4 and 5 of the acquired Landsat 2021 image were extracted using the NDVI formula:NDVI = (Band 5- Band 4)/(Band 5+ Band 4).

3.8: Processing the Landsat 8 imagery

Two Landsat 8 Geotiff raster obtained in 2019 with 30 meters' resolution were analyzed and mosaicked using the raster mosaic tool in the raster extension of ArcGIS toolbox to give a single raster.The composite bands tool in the raster extension ArcGIS toolbox was used to create composite bands comprising bands 2,3,4 and 5. Supervised classification was done for the data set using the classification toolbar in ArcGIS.

3.9: An Application of AHP/PCM Generation and weighting of fadama determinants variables.

Analytical Hierarchy Process (AHP) and Pairwise Comparison Method (PCM) were employed to be the most widely accepted method and the most consistent MCDM method that helps to measure the weight of criteria with respect to another (Getachew and Solomon, 2015). The following criteria were integrated to model suitable sites for fadama within the study area: relief, slope, rainfall, soils, vegetation and drainage density. To produce zones for Fadama, weights were assigned to each criterion since the criteria have unequal contribution on suitability for fadama sites. To apply the method in this research, four (4) major steps were followed; Development of AHP/PCM, Normalization of the criteria, calculation of weight of each criteria and testing of the consistency index. According to Saaty (2012), high value denotes high scale and low value denotes low scale. Normalization is the next step after the PCM, in normalization, row value of a criterion is divided by the column total of the criterion. The same procedure was applied to the entire criterion. To obtain the exact weight and rank of each criterion, average of each row was calculated and the values were ranked based on hierarchy. The last step is the test of consistency, in AHP application, it is expected that there is consistency in assigning weight

The following steps were followed to build the AHP/PCM for modeling suitable sites for fadama development.

(i) **Development of the Hierarchy.**

Pearwise comparison scale based on Saaty and Vagas (2012) AHP method was adopted in building the hierarchy as shown in Table 3.5.

Table 3.5: Saaty's pairwise comparison scale

Numeric value	Verbal Judgment
1	Equally importance
3	Moderately more importance
5	Strongly more importance
7	Very strongly more importance
9	Extremely importance
Reciprocals	Values for Inverse Comparison

Source: Saaty and Vagas (2012)

(ii) Prioritizing the variables (Criteria)

Since each of the criteria has different influence on the suitability modeling, the influence of the criteria was measured. The values in the diagonal must be one (1) as shown in Table 3.6

Table 3.6: Priorities for variable (criteria)

Criteria	Relief	Drainage Density	Soils	Rainfall	Slope	Vegetation
Relief	1.00	2.00	2.00	2.00	2.00	2.00
Drainage Density	0.20	1.00	2.00	2.00	2.00	2.00
Soils	0.20	0.20	1.00	2.00	2.00	2.00
Rainfall	0.20	0.20	0.20	1.00	2.00	2.00
Slope	0.20	0.20	0.20	0.20	1.00	2.00
Vegetation	0.20	0.20	0.20	0.20	0.20	1.00
Total	2.00	3.80	5.60	7.40	9.20	11.00

Source: Developed by the researcher, (2024)

Taking Relief row for instance, the 2.00 of relief under drainage density means that drainage density and relief fall between equally important (1) and moderately more important (3). The 0.20 (1/5) of drainage density under relief means that relief is strongly more important (5) than drainage density, drainage is just equally important than drainage

(iii) Generation of Normalized matrix

The generated overall weights of the criteria, is known as normalized matrix as shown in Table 3.7. To obtain the weights of the criteria, the values of the first cell in the first column of the first table (Table 3.7) was divided by the values of the total column of the first Table in order to obtain the value for the first cell of the second table (Table 3.7). For example, the value 0.50 of the first cell in Table 3.7 was obtained by dividing the total value of the first cell (1.0) in Table 3.7 by the total of the column (2.0). The addition of all the values in each of the rows give the weights of each criteria as presented in Table 3.7.

Table 3.7: Prioritization and weights matrix of the six criteria

	Relief	Drainage Density	Soils	Rainfall	Slope	Vegetation	Weight	Weight%
Relief	0.50	0.53	0.36	0.27	0.22	0.18	0.34	34.22
Drainage Density	0.10	0.26	0.36	0.27	0.22	0.18	0.23	23.16
Soils	0.10	0.05	0.18	0.27	0.22	0.18	0.17	16.68
Rainfall	0.10	0.05	0.04	0.14	0.22	0.18	0.12	12.04
Slope	0.10	0.05	0.04	0.03	0.11	0.18	0.08	8.43
Vegetation	0.10	0.05	0.04	0.03	0.02	0.09	0.05	5.47
	1.00	1.00	1.00	1.00	1.00	1.00		

Source: Developed by the researcher, (2024)

(iv) Generation of Consistency Index

Consistency ratio was carried out to minimize the problems of inconsistency during decision making in the ranking of the criteria for pairwise comparison Table 3.8

Table 3.8: Consistency Ratio of the criteria

Criteria	Relief	Drainage Density	Soils	Rainfall	Slope	Vegetation	Sum	Average
Relief	34.22	68.43	68.43	68.43	68.43	68.43	376.37	11.00
Drainage Density	4.63	23.16	46.33	46.33	46.33	46.33	213.10	9.20
Soils	3.34	3.34	16.68	33.36	33.36	33.36	123.42	7.40
Rainfall	2.41	2.41	2.41	12.04	24.09	24.09	67.45	5.60
Slope	1.69	1.69	1.69	1.69	8.43	16.86	32.04	3.80
Vegetation	1.09	1.09	1.09	1.09	1.09	5.47	10.93	2.00
								39.00

Source: Developed by the researcher, (2021)

Eigen value = 39.00/6 = 6.5

Consistency Index (CI),

= CI = $(\lambda_{max}-n)/(n-1)$

Where:

λ_{max} = eigen value = 6.5

n = number of criteria = 6

CI = (6.5-6)/(6-1) = **0.1**

Table 3.9: Values of R1 with n. order of the Matrix by Saaty and Vagas 2012

N	2	3	4	5	6	7	8
RI	0.00	0.52	0.90	1.12	1.24	1.32	1.41

Source Saaty and Vagas (2012)

RI for six criteria is **1.24**

Consistency Ratio (CR) = CI/RI (CI=0.1 while RI =1.24)

Therefore: CR = 0.1/1.24 = 0.08

Saaty and Vagas (2012) stated that CR values of equal to or less than 0.10 is acceptable for AHP. Therefore, since 0.08 is less than 0.10, the weights of the AHP can be used to weight the influence of each criteria using the weighted sum in ArcGIS for image overlay of the six criteria

RESULTS AND DISCUSSION

The six integrated criteria (drainage density, rainfall, relief, soils, slope, and vegetation for modeling for fadama Ecological services zones in the study area are discussed.

4.1. Relief Classes of Biu Plateau

Based on the relief of Biu Plateau, the fadama are the low floodplains areas where the relief is low, most soils in the area are impermeable which reduces water percolation and increases the ability of the soils to retain water, high rainfall and forest/woodland vegetation. The high suitable areas for fadama are found in large areas in Shani, Bayo, Kwaya Kusar and along the valleys of River Hawul (Fig. 4.1). The potential fadama areas were also found largely along the main river valleys within the area such as Gongola, Hawul and Ndivana. Some of the main settlements within the high suitable sites for fadama are; Shani and Briyel in Shani and Bayo LGA respectively. The moderately suitable areas for fadama are the high floodpains with higher relief than the low floodplain areas. Fadama in these areas are not as suitable as those in the low floodplains because the conditions of the area for fadama suitability such as soils, relief, rainfall, and vegetation are not as conducive as those in the low floodplains.

The foot of Biu Plateau where Mandaragirau, Tashan Alade in the east and Nderi in the west are located at the marginally suitable areas. The Biu Plateau itself within the study area falls under unsuitable sites. the nature of the relief, soils, vegetation and drainage density. Biu, Buratai, Alagarno, Azare and Yimrishika fall in this zone. The spatial pattern of site suitability for fadama is presented in Fig. 4.1

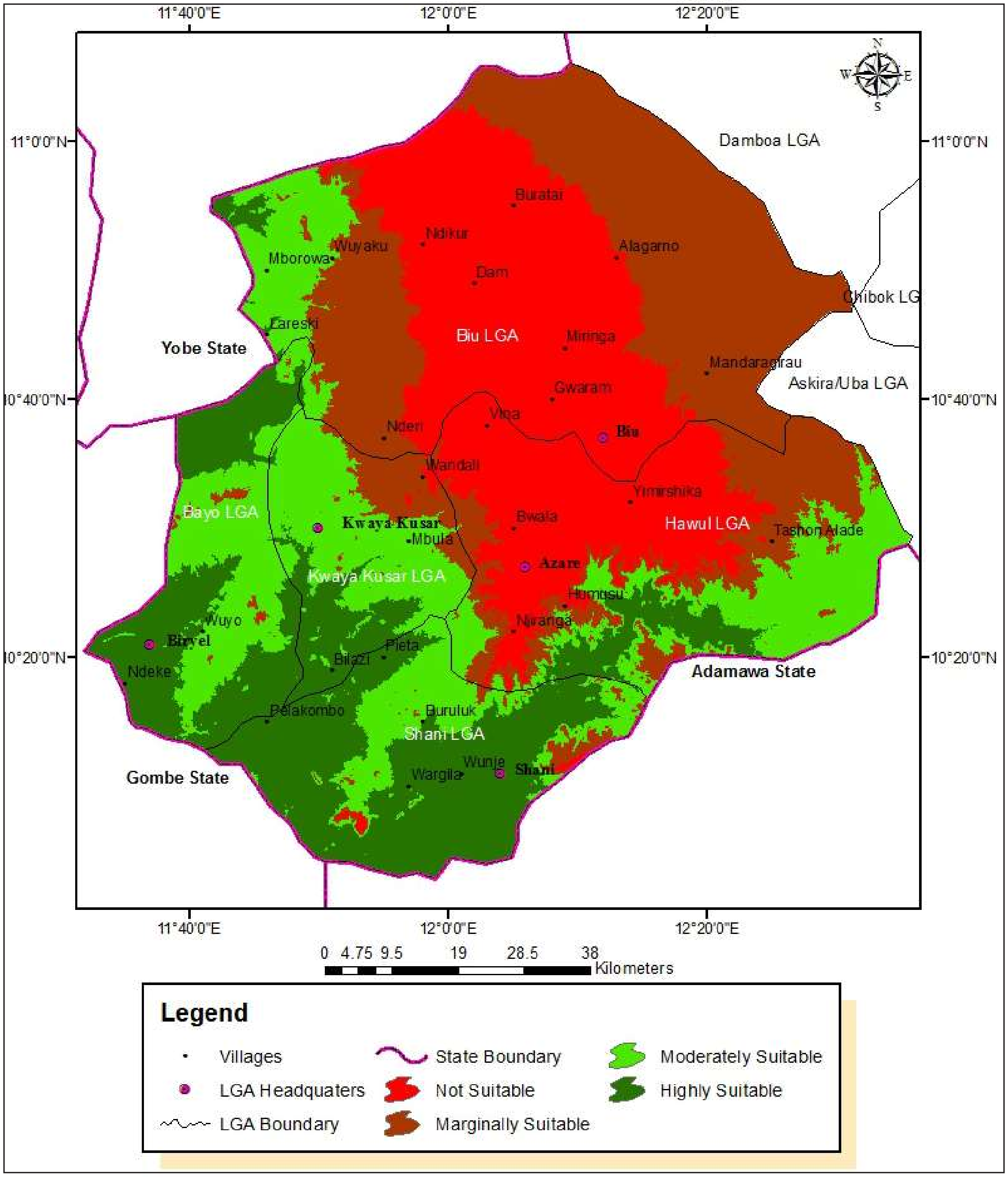

Figure 4.1. Classified relief of Biu Plateau

Source: Analysed DEM from United state geological survey, 2024.

Figure 4.1 shows that major parts of fadama falls within Bayo, Kwaya Kusar and Hawul LGA. Table 4.1 shows the fadama suitability classes. The table also reveals that more than half of the entire study area is either marginally or completely unsuitable for fadama sites within the study area. Only a land area that is less than 30% are very suitable for fadama sites. The nature of the soil of Biu Plateau as stated by Abdullahi (2014) is volcanic in origin and is characterized mainly by sandstone, granite gneiss, biotite and basalt rocks. The possible fadama ecological services in the low floodplains include surface water in form of ponds, lakes, rivers or streams. Others include vegetation for grazing (especially during the dry season) and medicinal purposes. The soils of the areas are also utilized for irrigation agriculture especially rice, sugar cane and orchards.

Table 4.1. Relief classes for Fadama

Relief Classes(m)	**Area (km^2)**	**Percentage**
176-315	1768.87	21.49
315-446	1928.37	23.43
446-595	2256.74	27.42
595-952	2277.34	27.67
Total Area	8231.32	100

Source: Calculated from SRTM DEM data

The relief of the study area is classified into four classes viz upland the height covers between 595-952 meters, hills covers between the height of 446-595 meters, relatively flat plains covers the height of 315-446 meters and flat plains covers the height between 176-313 meters which is 21 percent of total area on Biu Plateau. The relatively flat and flat plains have potentials and capacity of holding water that resulted on Fadama suitability in those locations. It also forms rivers channels flood plains (Fig 4.1). The flat (176-313 m) areas best describes areas that are marsh or Fadama in nature. The highest point of the area is located from the north and eastern parts of Biu local government area which channel the water flow towards the lowland to the south and western part of Biu plateau.

4.2 Drainage Density of Biu Plateau

The number of streams in an area commonly referred to as drainage density has much impact on the wetness or dryness of an area which in turn a strong factor in the determinants of fadama area. The higher the drainage density, the wetter the area is and vice versa. Mahamat *et al,* 2020 opined that drainage density directly related to components such as infiltration, run- off, river, lithology, climate and vegetation cover or landuse/landcover. The drainage density of the plateau could indirectly be the determinants of resources due to surface water and impermeability of the soil in certain areas on the Plateau. Areas characterized by highly resistant or permeable subsoil material, low relief and dense vegetation tend to have low drainage density which to suitable fadama area (Fig.4.2)

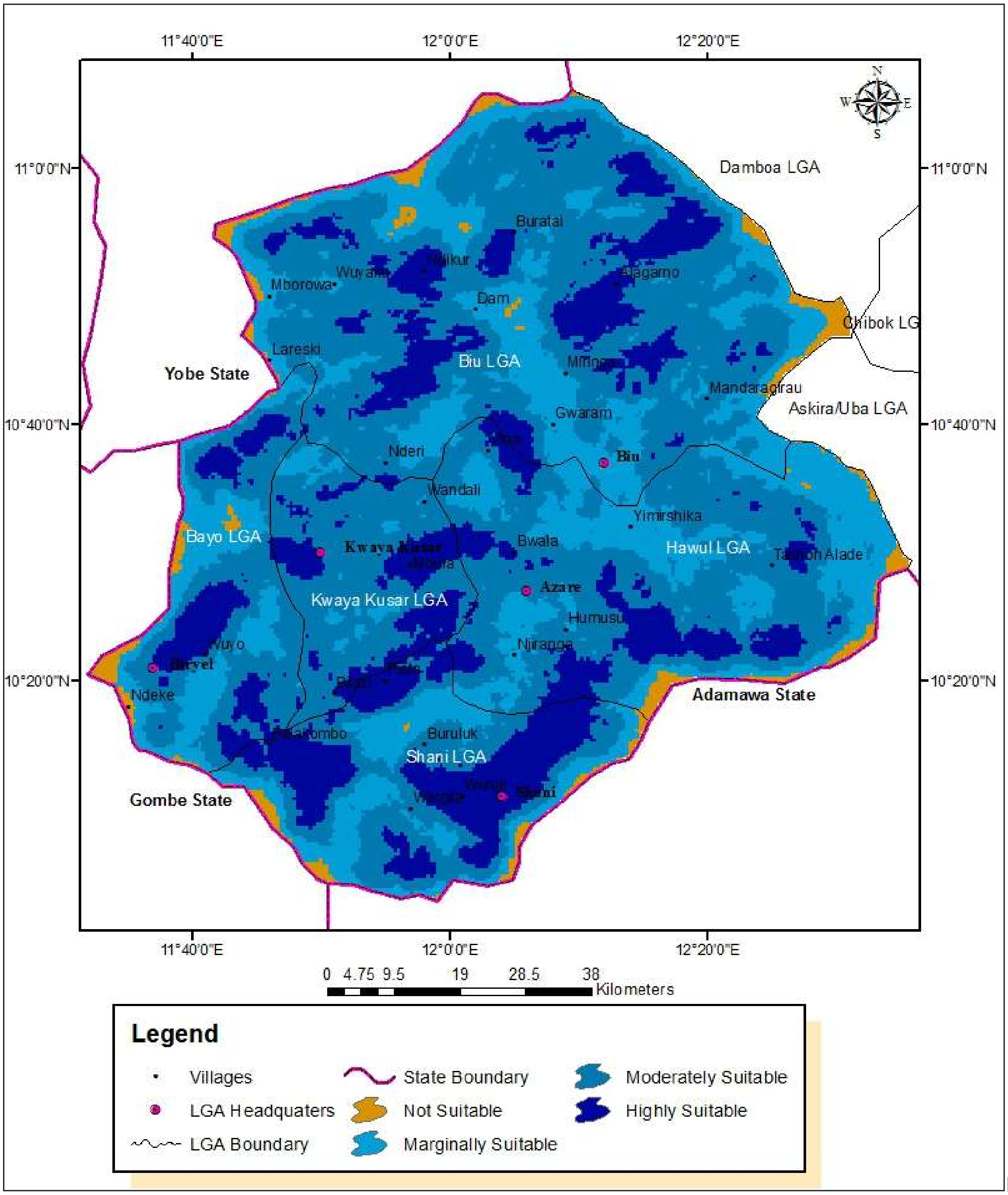

Figure 4.2. Classified Drainage density of Biu Plateau

Source: Analysed from United states geological survey, 2024.

4.3. Rainfall of Biu Plateau

Rainfall is among the strong determinants of fadama areas. Figure 4.5 shows the suitability pattern of rainfall for fadama sites. If an area meets all other conditions like soils, slope, drainage density and vegetation cover without rainfall, such an area can never be a fadama area. In the study area, the mean rainfall of the entire southern part as well as the southern half of the plateau were found to be good for fadama development while the northern extreme with low mean rainfall were found to be unfavorable. Mean annual rainfall in the region as found in this study ranges from 856.5 to 900.5 mm, with rainfall onset in April and cessation in October.

The role of rainfall on fadama areas cannot be overemphasized because it determines the wetness or dryness of the soil which in turns affect the kind of fadama area. Rainfall also determines the thickness or the non-existence of vegetation in an area. Most importantly rainfall largely determines the amount of ecological services that are based on water as water availability mainly depends on rainfall amount and the soil types of the areas.

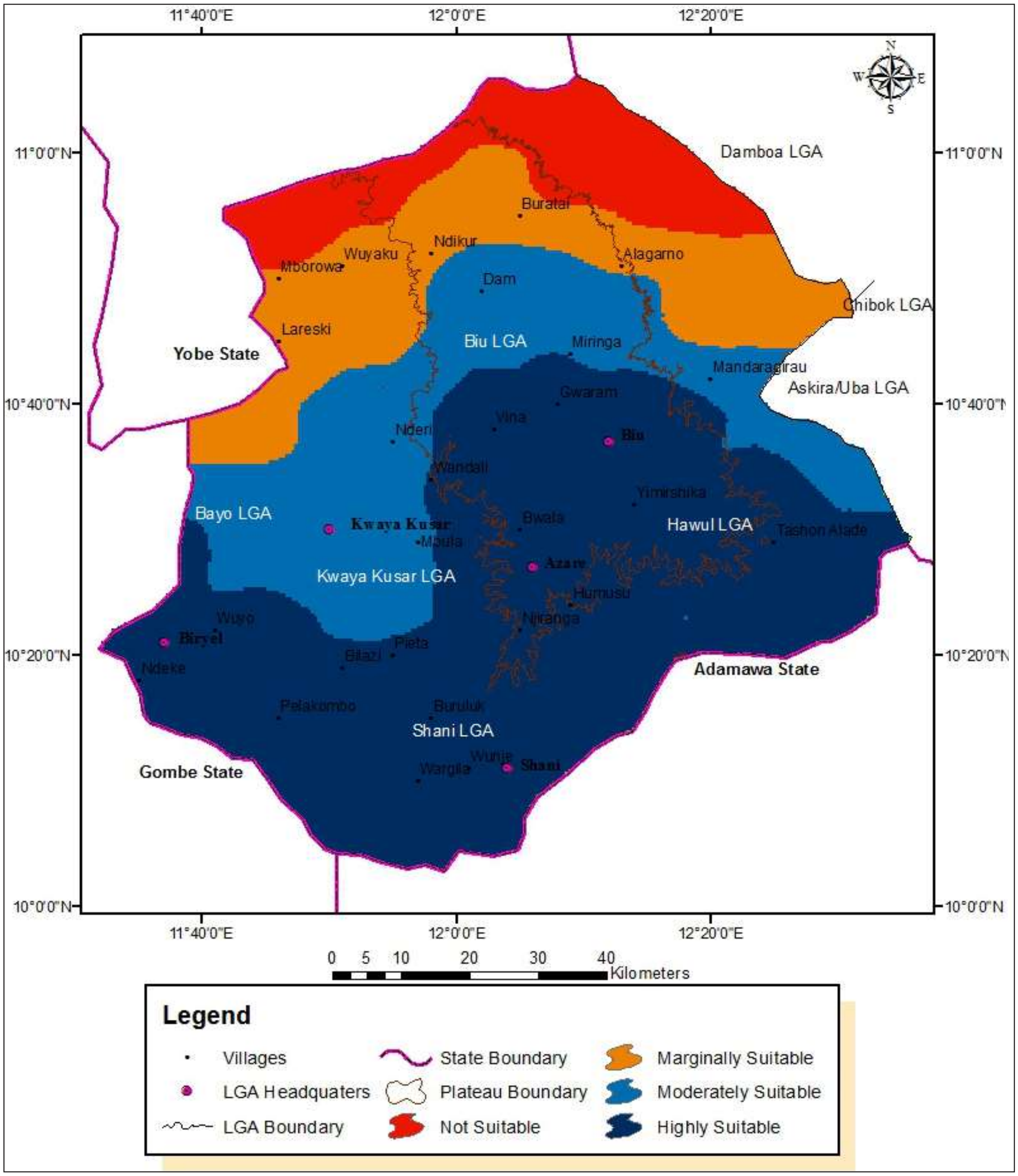

Figure 4.5.
Classified mean rainfall of Biu Plateau
Source: Adopted and Modified from MANR, 2024.

4.4. Soils of Biu Plateau

The spatial patterns of soil for fadama is presented in Fig. 4.4, while the area and percentages covered by each of the soil units is shown in Table 4.4. Table 4.2 shows that based on soil alone, only a small portion of the study area is good for fadama. This finding is not surprising because the main soils of the plateau are basic complex which are hard rocks where water retention is difficult as reported by Alka & Arvin (2017) that the soil of a place does not only determines the nutrient composition of a place but also determines the water retention capacity that will support the growth and yield of crop. The plateau section of the study area is mainly covered by Leptosols and Phaeozems. Leptosols are shallow and stony soils with low water holding capacity, Phaeozems has high permeability and therefore also cannot hold water which makes the Plateau to be not favorable for fadama formation. However, the foot of the plateau especially in Bayo, Kwaya Kusar and Shani LGAs are covered by Luvisols, Fluvisols, Leptosols and Arenosols. While Luvisols and Fluvisols are soils that are frequently flooded and therefore suitable for fadama formation, Arenosols are sandy-textures soils with excessive permeability and lacks clay accumulation (Ikusemoran 2018) which are not good for fadama because of their low water holding capacity.

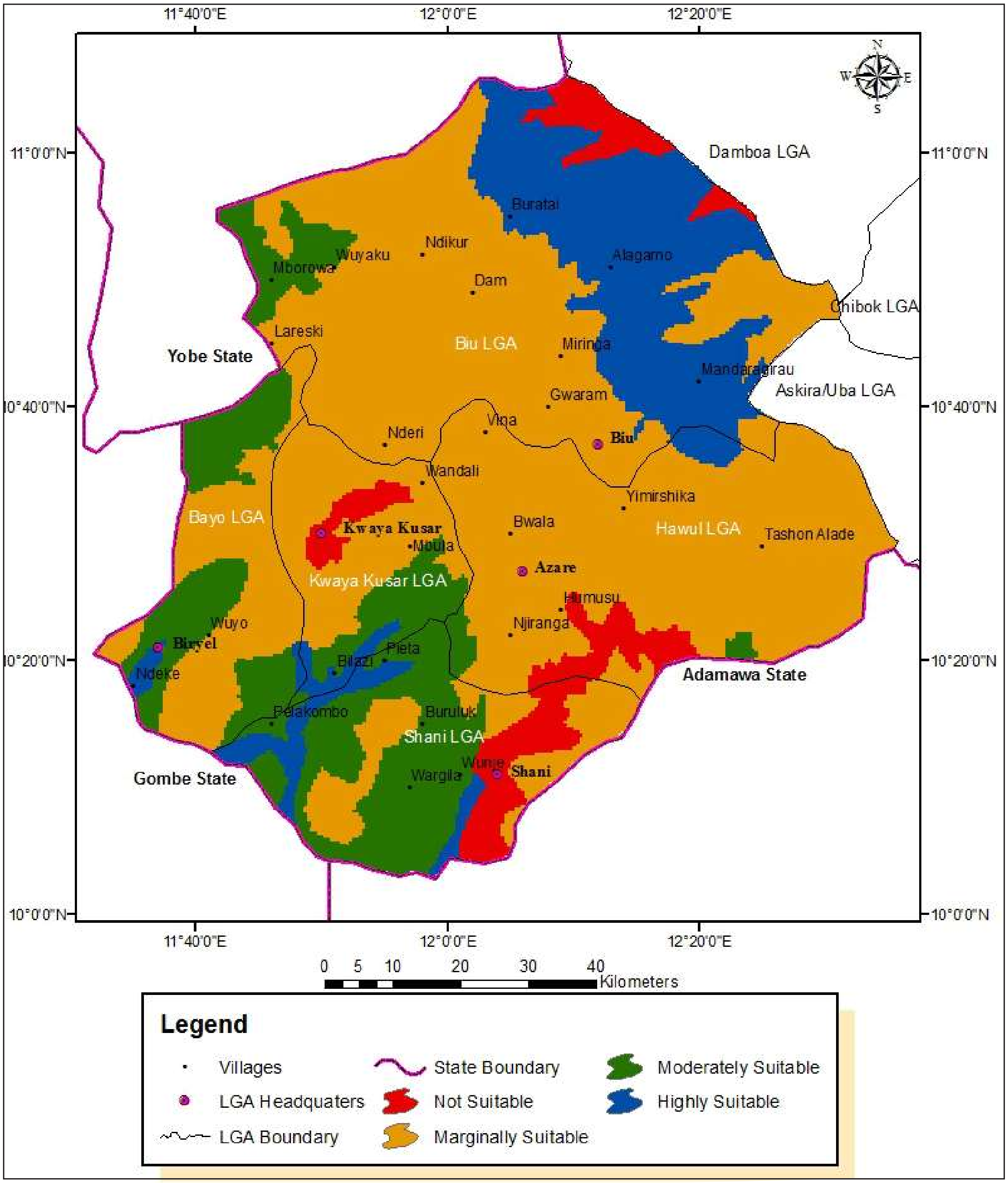

Figure 4.3.

Classified soil types of Biu Plateau

Soruce: Extracted and modified from sonneveld, 2024.

4.5. Vegetation of Biu Plateau

Figure 4.5 shows the partial pattern of the classified vegetation for fadama development in the study area. The figure also shows that non-vegetated areas are mainly found at the top of Biu plateau which is mainly characterized by basement complex rocks mainly phaeozems and Leptosols. Both soil units had been identified to consist of highly permeable, free draining and low water holding capability (Abdullahi 2014, Ikusemoran, 2017). Therefore, the areas are devoid of vegetation mainly because of the nature of the soil. Built up areas and their environs on the plateau such as Biu, Buratai, Tashan Alade and Azare are also places of depleted vegetation which might be connected with the effects of anthropogenic activities such as residential development, farming, fuel wood harvesting and bush burning. The valleys of River Hawul was also found to another place of little or no vegetation which can be attributed to the fact that the area is made up of Arenosols soils which is sandy and highly porous with very low water holding capacity. All these characteristics of the soils in the area subject the place to scanty or no vegetation because the soils are dry especially during the dry season and hence cannot sustain dense plant growth.

Amongst the few areas with woodland vegetation are the eastern part of Biu LGA which has been found in this study to be areas of low relief, almost flat slope with Gleysols types of soils which is clayey and not highly permeable with high water holding capacity. Other woodland areas include: the riparian vegetation along the valleys of major rivers such as Ndivana which is suitable for fadama area.

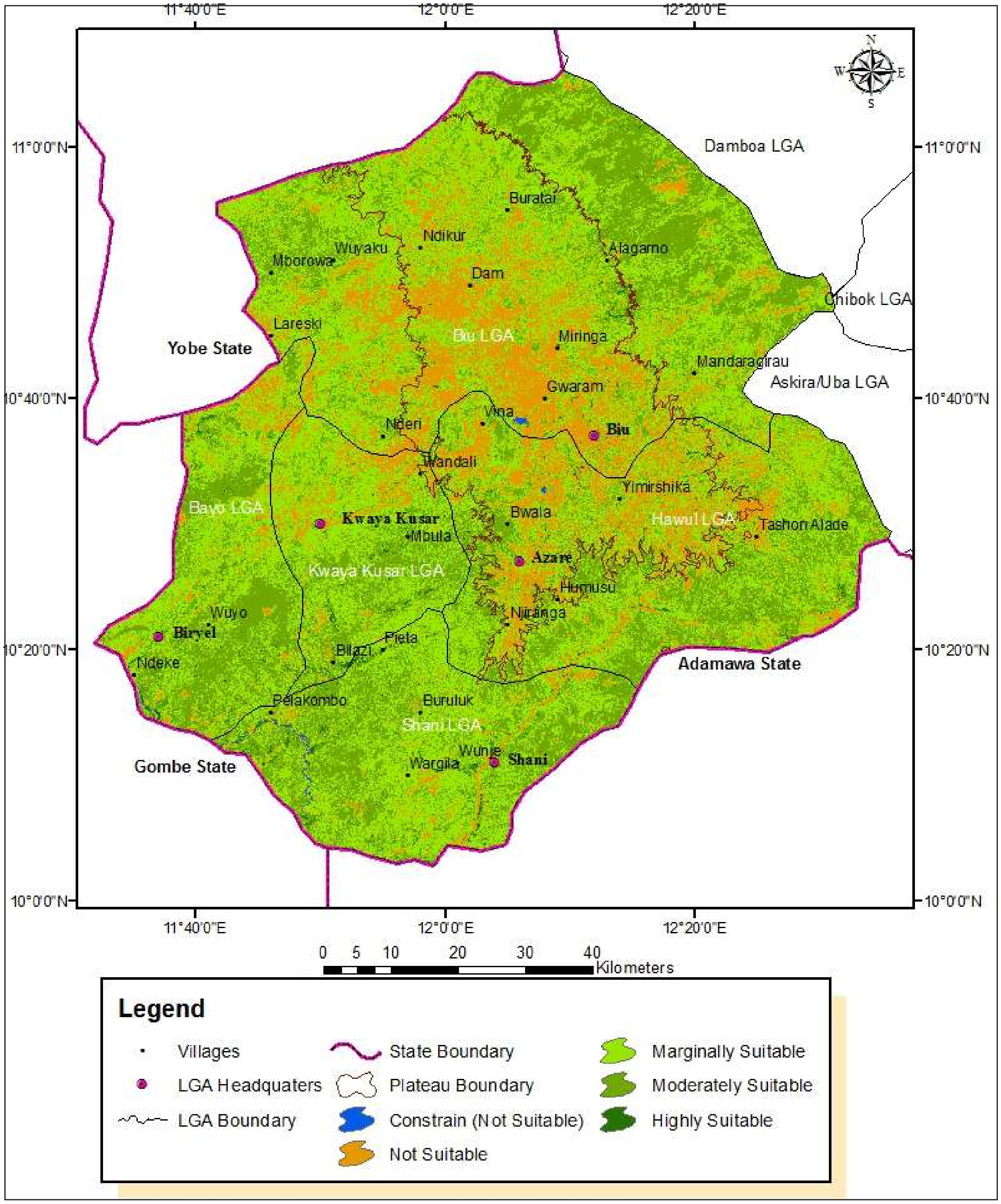

Figure 4.5. **Classified vegetation of Biu Plateau**
Source: Analyzed from NDVI, 2024.

4.6. Slope of Biu Plateau

Slope is one important determinant of fadama development. Slopes affect fadama development in two ways: the thickness of soil cover and water retention. Steep slope areas are usually a region of thin-layered soils and gradual down movement of the underground water which leads to the early and prolonged dryness of the soils. These thin-layered soils and dryness of soil make steep slope areas to be inapt for fadama.

Fig. 4.6 shows that almost flat areas of the north-eastern side of Biu LGA is highly suitable for fadama development. The eastern-central parts of Hawul LGA and some isolated hills in Shani LGA however were found to be regions of steep slopes which are not suitable for fadama development.

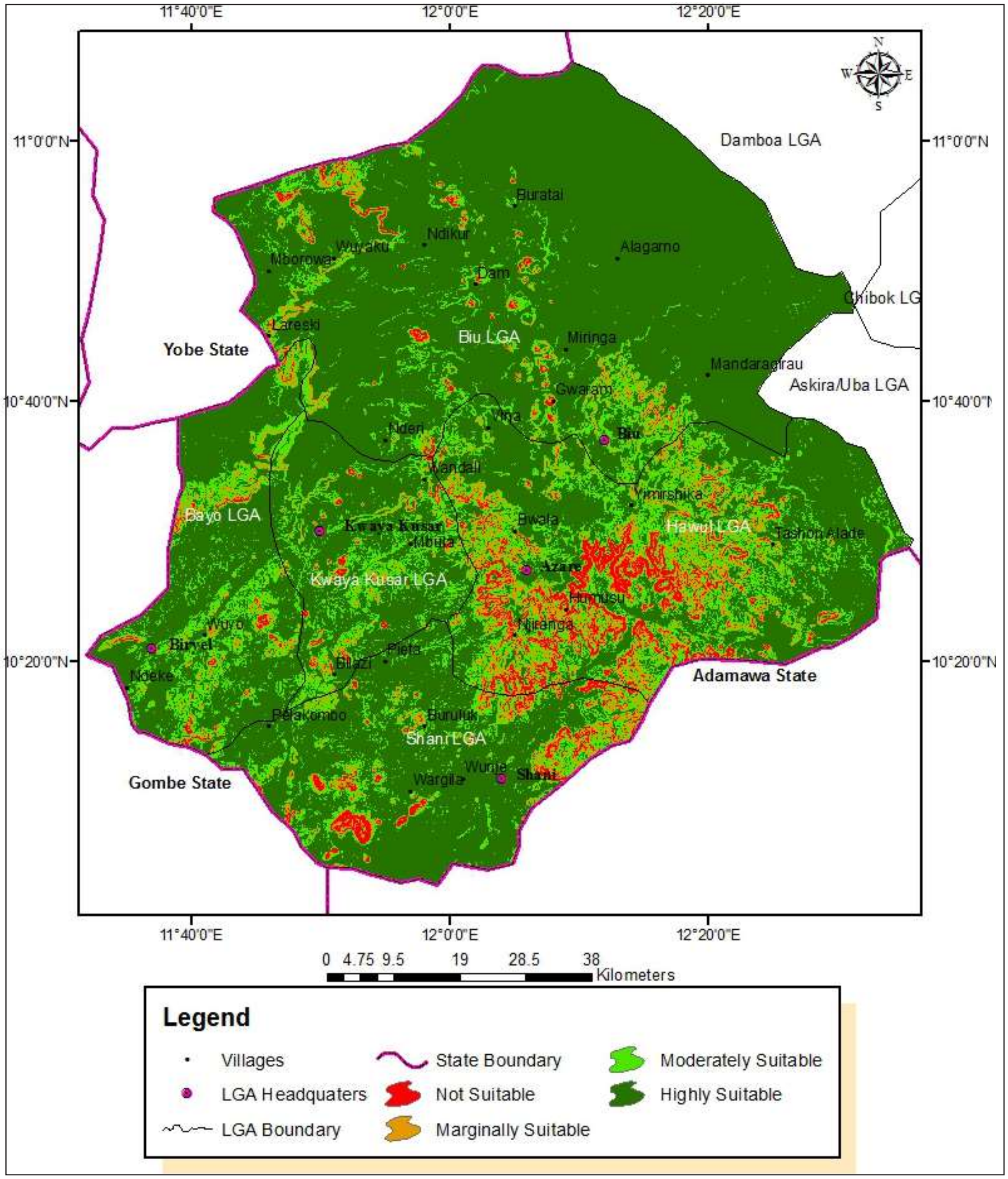

Figure 4.6.
Classified slope of Biu Plateau
Source: Analyzed from Digital Elevation Model of USGS, 2024.

4.2 Fadama zones

Fig. 4.8 shows the fadama suitability map of the study area. Very suitable fadama sites are found mainly at the southern part of the plateau including Shani, Kwaya Kusar, Bayo and along River Hawul in southern Hawul LGA. The valleys of the main Rivers such as Hawul, Ndivana and Gongola were all very suitable for fadama development which confirms with the assertion of Datung, Fadare and Adereti 2017, Godwin and Choji, 2017, fadama areas are low laying lands that are subjected to seasonal flooding or water logging along the banks of streams or depressions. The very suitable as have been assessed in this study are areas with high rainfall, suitable soils like fluvisols and luvisols which have high water holding capacity, low relief, relatively dense vegetation and undulating slope areas. Shani and Briyel settlements are situated within very suitable areas.

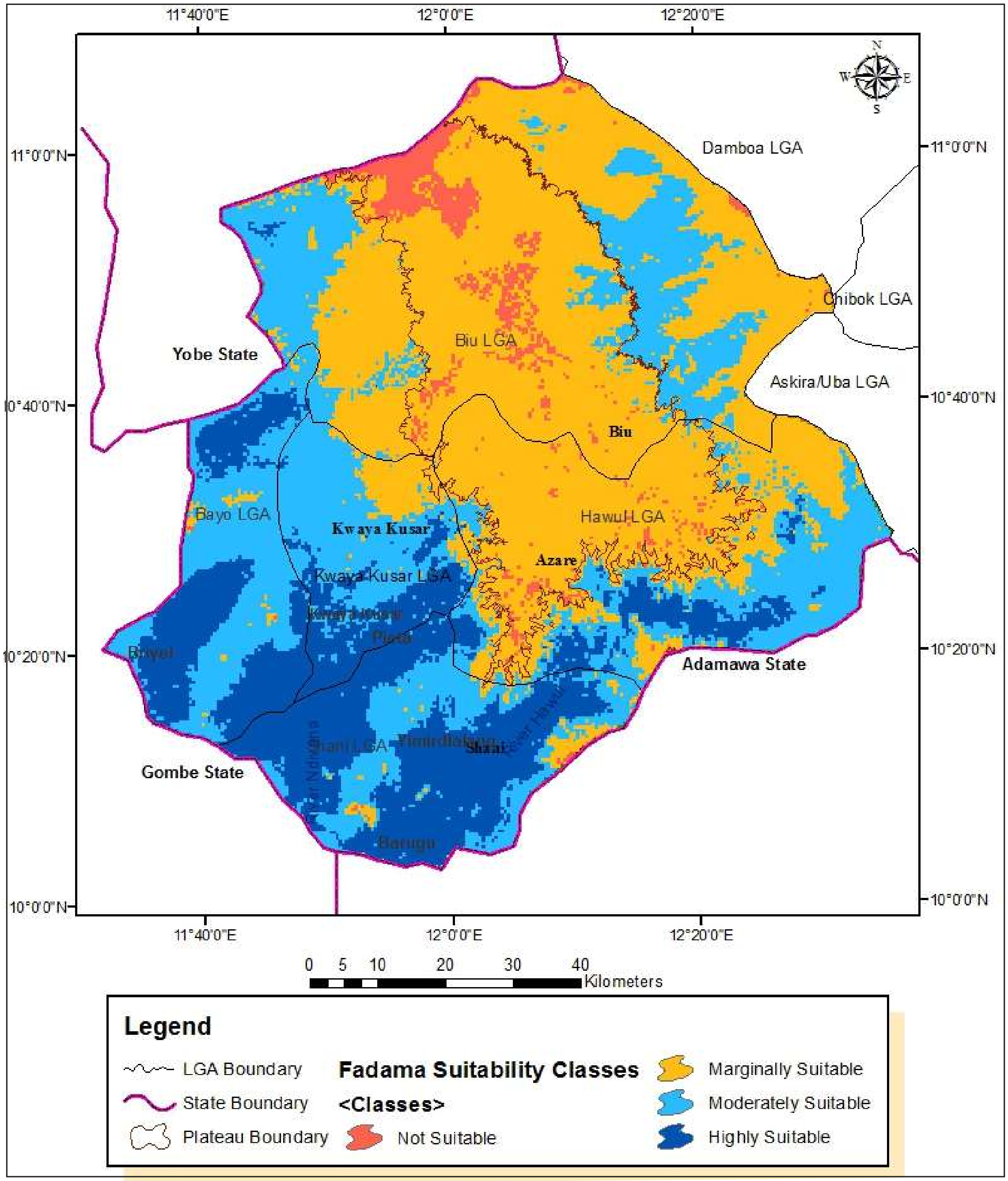

Figure 4.8. **Fadama suitability map**

Source: Author's work, 2024.

The moderately suitable areas are found mainly around the high floodplains zone of the study area. The zone is also mainly found in the same LGAs with very suitable areas. However, moderately suitable areas are also found at the eastern and western part of Biu LGA. The suitability at the western side is due to low terrain, high drainage density, moderate vegetation, relatively flat slope and moderately suitable soils. The soils of Fadamas varies in their texture ranging from sands to loams and give rise to variations in their physical and chemical properties (Borno State Agricultural Development Project [BOSADP], 2008). At the foot of the plateau in the eastern part of

Biu LGA explicitly from Alagarno southward to Mandaragirau where the soils are highly suitable relief, vegetation and slope are highly suitable were zone as moderately suitable for fadama development. Almost the entire plateau is either not suitable or marginally suitable for fadama which might be attributed to the presence of basic complex rocks with low water holding capacity, sparse vegetation, high relief and slope and low drainage density. The soils, water, vegetation and other features in each of the suitability zone dictates the types and extent of fadama ecological services that are likely existing in each of the zones.

Table 4.3: Fadama zones

LGAs	Fadama land	Percentage
Bayo	430.34	26.32
Biu	5.92	0.36
Hawul	183.79	11.24
Kwaya	218.95	13.39
Kusar		
Shani	796.30	48.69
Total	1635.3	100

Table 4.3 shows the area covered as well as the percentages of each of the fadama zones. Rock outcrop, grassland and shrub areas cover almost half of the total study area (48.99%). Only about 20% were considered to be fadama land which is connected to the fact that large portion of the study area is covered by Biu Plateau with hard rocks, thin and dry soils which combined together to render the plateau as unsuitable for fadama development. Almost half of the fadama areas are found in Shani LGA which are drained by the two main rivers (Hawul and Ndivana) and which impacted on the L.G.A for fadama development. Other than the effects of the rivers, the area is also of low relief except some dotted hills which are categorized as rock outcrop and shrubs areas within the L.G.A. The soils of the area also contribute immensely to the fadama in the area as postulated by Millennium Ecosystem Assessment, (2014) that soil is the foundation of all terrestrial ecosystems and the agricultural and forestry provisioning services, as well as being the structural medium for supporting the terrestrial biosphere and infrastructure.

Table 4.3 also revealed that almost half of the fadama land area are found in Shani LGA which might be connected to the fact that the two main Rivers (Hawul and Ndivana) converge in the L.G.A which drains and provides an extensive land area for fadama as noted by Datung et al., (2017) that Fadama are waterlogged during raining season and retained moisture in the dry season or a low lying-lands relative to other areas adjacent to the river or stream which are characterized by water logged or flooded during the raining season. Less than 1% of the Fadama in the study area are found in Biu L.G.A which might be attributed to the unconducive soils of the area for Fadama development, low drainage density, steep slope with thin soil cover which easily becomes dry during the dry season, sparse vegetation and high relief. Areas liable to flooding and which is characterized by fertile soils have been identified by Godwin and Choji, (2017) to be suitable sites for Fadama.

Conclusion

The research was on suitability analysis of fadama areas in Biu plateau region of Borno. an AHP approach. The aim was to determine Fadama suitability areas in Biu Plateau region using GIS and AHP method. The objectives were to: examined the fadama suitability areas through physiographic and to map out fadama suitable areas in the Biu plateau. The determinants or physiographic determined the fadama areas in the Plateau (relief, slope, soil, rainfall, vegetation and drainage density).

The suitable areas are found mainly around the low floodplains zone of the study area. However, moderately suitable areas are also found at the eastern western and southern part of Biu Plateau. The suitability at the western side is due to low terrain, high drainage density, moderate vegetation, relatively flat slope and moderately suitable soils. At the foot of the plateau in the eastern part of Biu LGA explicitly from Alagarno southward to Mandaragirau where the soils are highly suitable relief, vegetation and slope are highly suitable were zone as moderately suitable for fadama development. Almost the entire plateau is either not suitable or marginally suitable for fadama which might be attributed to the presence of basic complex rocks with low water holding capacity, sparse vegetation, high relief and slope and low drainage density. The major part of the fadama are also located in Shani, Bayo and Kwaya Kusar,

Recoommendations

At the end of the research the following recommendations were drawn;

i. The Fadama suitable land was mapped out for easy identification to the users, as such government should secure the area for judicial use.
ii. In the quest for developing the Communities in the study area and Nigeria in general, the government should make Fadama activities attractive for youth to participate fully in Fadamaactivities; this could serve as a way of reducing poverty and fostering development.
iii. Government and NGO and CBOs should create awareness to women on the relevance of the fadama areas. This will also help in achieving the aim of the united nations whose focused on women and children as the most vulnerable in society.

References

Abdulkadir M, Mallam I and Mohammed S, (2019) Classifications using MCE and AHP on Fadama lands of River Challawa, Kano State, Nigeria.

Abdullahi, J., Odihi, J. O. and Wanah, B.B., (2015). Analysis of Morpholgy of Volcanic Craters on the Biu Plateau, Borno State, Nigeria.*Journal of Geography, Environment and Earth Science International. Science domain.*

Borno State Agricultural Development Programme (BOSADP) (2008)., Office Memo File

Cheng, X., Sylvie, V. D., Luyuan, L. & Pieter U. (2019) Evaluation of cultural ecosystem services: A review of methods. Elsevier. Science Direct.

Fadare, I. A, and Adereti, F.O., (2017). Assessment of the level of Fadama III Project Implementation among Fadama Users Group in Osun State, Nigeria. *International. Journals of Forestry and Plantation.* Vol. 5.

Folayan, J.A. (2013).''Socio-Economic Analysis of Fadama Farmers in Akure South Local Government Area of Ondo State''. *American Journal of Humanities and Social Sciences*. Vol. Ino.l.pg no .10-17.

Musa, M. & Adamu, M.M. (2016). Socioeconomic profile of Fadama Farmers Jere bowlJere local government, Borno State. Presented at the international conference on humanities, science and sustainable development. Rivers state University of Science and Technology Port Harcourt, Nigeria.

Kuza, Y., Okwoche, V. A. and Age A. I.(2018). Assessment of the Impact of Fadama IIIDevelopment Project on Beneficiaries in Nasarawa. State. *Greener Journals of Agricultural Science,* Vol. 8 (9).

Ikusemoran, M. Manu, H and Yelwa, H.B (2018) Geospatial analysis of morphometric characteristics of river Hawul basin, North eastern Nigeria. Resource and environment 8(3)