Impacts of Land use and Land cover Change and Rainfall on Flood Occurrence in Bosso and Chanchaga LGAs of Niger State, Nigeria

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ABSTRACT

In recent times, flood occurrences have become an annual phenomenon resulting to irreplaceable loss of lives and properties. Land use and land cover changes are important for identifying long-term landscape effects caused by natural processes and anthropogenic pressure. Associated with post flood events, is the outbreak of diseases, pollution of the human environment and destruction of basic infrastructure. This research utilized both primary and secondary data, the primary data include geographic coordinates and personal observation while the secondary data is satellite imageries between (2003-2023) and 30m DEM. Geospatial techniques was used to analyze the data. Supervised classification scheme was for the analysis using ArcGIS to monitor the changes and other factors responsible for flood occurrence. Finding shows that built up areas increased from 71.55 km^2 (4.31%) in 2003 to 296.87 km^2 (17.90%) in 2023. *The result from the classified DEM also, indicates that about 329.62 square kilometer (19.87%) of the area is on lower elevation which is evidence of recurrent flooding in the study area. 406.47 square kilometer (24.51%) are on high-risk areas, moderate risk areas and 407.49 square kilometer (24.57%) are low risk areas while 331.18 square kilometer (19.97%) is on high elevation, indicating no risk areas. Findings also shows that slope, hillshade plays a significant role on flood occurrence. The findings are important to better understand ways towards sustainable management of natural resources as well as efficient methods to study these processes.*

Keywords: *GIS, Flood, LULC, Remote sensing, DEM and Rainfall data.*

1. INTRODUCTION

The rate of flood occurrence in recent times has been unprecedented. With 70 million people globally exposed to flooding every year, and more than 800 million living in flood prone areas (Nkwunonwo *et al*., 2020). In Nigeria, flooding has led to considerable socioeconomic wreck than any other natural disaster. It is apparent from several literatures that flooding is natural disasters across Nigeria in recent time (Nkwunonwo *et al*., 2020)

Exploring the influences of nature of the surface, rainfall duration and surface runoff on flood occurrences with emphasis on infiltration rate by Izham *et al.*, (2011). The study explored the possibilities to provide a technique through which nature of the surface and other auxiliary data can be integrated to soil saturation over relatively heterogeneous surfaces for complex decision on flood occurrences to determine vulnerable area. When dealing with complex heterogeneous surfaces such as built up, infiltration is significantly retarded due to the prevalence of modified surfaces that alter the general complexities of infiltration resulting to the occurrences of flash flood within a short period of time during rainfall events. This study offers useful conceptual framework of relating flood storm water to precipitation as a reciprocal to infiltration and elevation but is deficient in terms of magnitudes and intensity, in addition, extended precipitation of over 24hours were not effectively incorporated. Floods are often linked to extreme climate events (Balch*et al.*, 2020; Towner *et al.*, 2020). Towner *et al.* (2020), identify several factors contribute to their occurrence, including intense short-duration rainfall, topographical features, and human-induced factors such as urbanization and settlement expansion in flood-prone areas (Gigović*et al.,* 2017). Globally, floods are among the most common weather-related hazards, causing property loss, fatalities, and farmland destruction. Urban flooding studies in the study area remain scarce. The limited number of studies on this topic hinders a comprehensive understanding of the phenomenon, primarily due to the lack of extensive climate event data. Like in many developing countries, detailed records of rainfall and runoff data are seldom available in the study area. Globally, rapid increase in population in major cities has led to urban sprawl at an unprecedented rate which has increased the level of flood vulnerability of cities and urban areas.

The increasing urbanization generally is brought about by many environmental problems, such as the drastic change of land use and development of urban heat island and flood event. This study utilized geospatial application in urban flood risk analysis in Bosso and Chanchaga LGA of Niger state, Nigeria. These were done with the view to determining the effects of changes in land use/cover on flood occurrence in the area. Primary and secondary data were used for the study.

Study Area

Bosso and Chanchaga LGAs is located in Minna which is the capital of Niger State. It is one of the twenty-five local government areas in Niger State, with its headquarters in Minna with a land mass of 1,592 km2 (Dalil *et al.*, 2015).

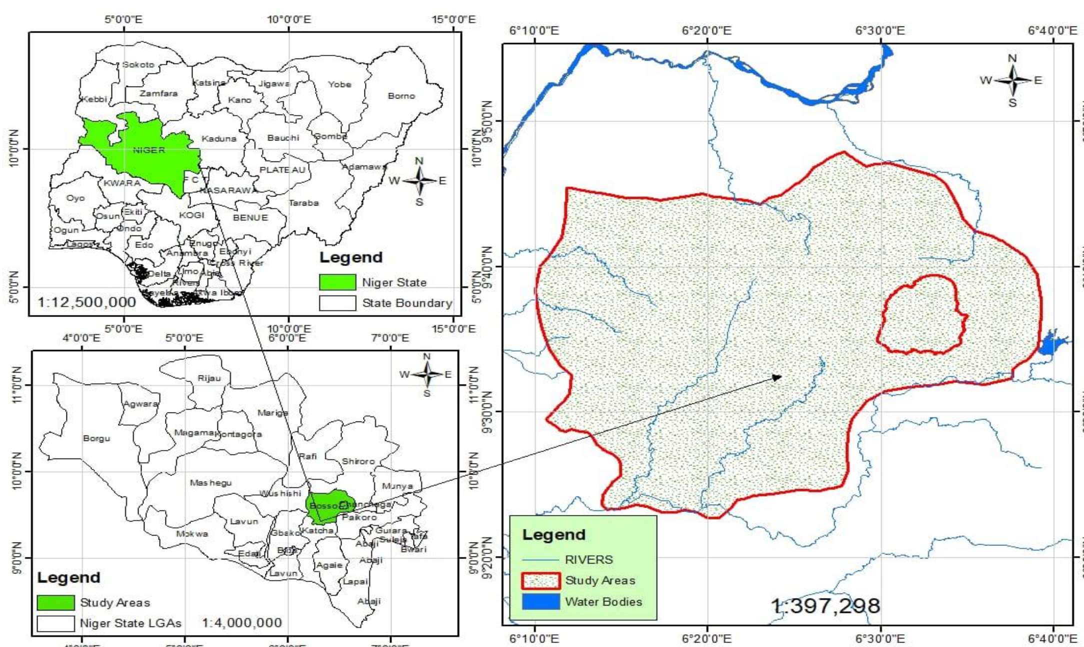

Figure 1: Map of the Study Area
Source: Department of Geography, FUT, Minna.

The study area is located between Longitude 9o 38"0 North and Latitude 6o 25"0 East (Figure 1.1). It covers a total area of about 297.5 km2 and has a population of about 147,359 as at 2006 census. Minna is a commercial urban area or more of a central place in Minna. The study area has two distinct seasons the dry and wet season. Precipitation per year varies between 1000-1400 mm on the average. The duration of rainy season ranges from 150 to 210 days or more from the north to the south. Mean maximum temperature remains high throughout the year, hovering about 37 oC and 20^{o} C respectively (Adeoye *et al*., 2018). However, the lowest minimum temperature occurs usually between December and January when most parts of the state come under the influence of the tropical continental air mass which blows from the north (Dalil et al., 2015).This study is aimed at analysis of impacts of land use and land cover change and rainfall on flood occurrence in Bosso and Chanchaga local government area, Niger state, Nigeria through a geospatial approach so as to achieve these specific objectives:

i. Identify the nature of rainfall between 2003 and 2023.
ii. Examine the land use and land cover between 2003 and 2023.

3. MATERIALS AND METHODS

The primary data used for the study is fieldwork and includes Photographs from the field GPS for picking geographic coordinates. The secondary data were sourced from the Earth explorer website. The Geo-referencing properties of 2003, 2013 and 2023 made up of universal Transverse Mercator (UTM) projection, and datum WGS 84, zone 32, IDRISI Terrset was used for the development of land use and land cover maps for the study areas. ArcGIS 10.3 was used in developing, displaying and processing of the location maps.

Table 1: characteristics of Landsat images used for the study

Date of Acquisition	Sensor	Path	Row	Multispectral Band	Thermal Band	Spectral Range (micrometers)	Spatial Resolution (pixel spacing)	Source
2003	TM	189	53	1to5 and 7	6	10.45-12.45	30	glovis.usgs.gov
2013	ETM+	189	53	1to5 and 7	6	10.45-12.45	30	glovis.usgs.gov
2023	OLI and TIRS	189	54	1to7 and 9	10 and 11	10.60-12.51	30	glovis.usgs.gov

3.1 DATA COLLECTION

3.1.1 Spatial Data Collection and Source

In order to determine the effects of LULC changes and rainfall on flood occurrence on the study area, spatial data-sets were obtained from Landsat7 and Landsat 8 archives from U.S Geological Survey (USGS), 30m DEM and ground observations obtained from Google Earth. The three data sets used for the study; its source of acquisition is shown in table 1 below. The Landsat data were obtained from the USGS and Earth Observation database. These imageries were selected based on date of acquisition and its availability. To prevent bias in the data, the images were of the same season free from cloud cover and have the same identifiable features. This gives uniform radiometric and spectral characteristic which helped reduce or prevent seasonal variation in the spectral reflectance of the land cover data-sets (Nzunda, 2013). Also, the data were georeferenced to the coordinate system of the study area i.e. WGS84 projection; UTM zone 32N.

Table 3.2: Software Components of the Research

S/N	Software	Purpose
1	Idrisi & ArcGIS 10.3	GIS analysis & classification of the Landsat images
2	Microsoft Excel	Statistical analysis for the calculation of percentage
3	Global Positioning System	For picking geographic co-ordinates

3.2 DATA ANALYSIS

The acquired Landsat imagery was analyzed using ArcGIS 10.8, Idrisi Terrset, Google earth and MS Excel. The methods used in processing the imagery for this study was image extraction of study area of interest (AOI), image restoration/ pre-processing, image enhancement and image classification. Image Pre-processing for mapping or analyzing the change in the land cover, Geometric restoration gives the accurate orientation of the satellite images, thus geo-referencing of the imagery. The imageries acquired were already geo-referenced from the World Geodetic System (WGS84); they were re-projected to the coordinate system of the study area, i.e. Universal Transverse Mercator (UTM) zone 32 North for Nigeria using ArcGIS version 10.8.

Image Enhancement: This technique deals with modification or improving the quality of the imagery, making it more suitable as perceived by humans. In order to improve the visibility of the imagery, a colour composite for the imageries were established using Landsat TM bands 4, 3 and 2 (i.e. Near infrared, Red and Green) and this gave a false colour composite.

Image Classification: The imageries were classified using supervised classification method prior to the knowledge of the study area available at hand. Anderson *et al.* (1987) level one classification method was used. This method involves extracting land cover information from the imagery and it is mostly referred to as clustering. The main objective for classification was to produce a land cover classes that resemble the actual land cover types of the earth surface (Sunday *et al.*, 2020).

4 RESULTS AND DISCUSSION

4.1 Analysis of the various Land use/Land cover (2003, 2013 and 2023)

The classification results for the LULC changes of the study area (Bosso and Chanchaga) were presented using charts and figures for illustration and interpretation of all land use/land cover classes of the study area.

4.1.1 Analysis of 2003 land use/land cover classification for the Study Area

Studies on land use change and urban expansion have become critical for environmental monitoring and changes over time and space for better decision making by policy makers. The land use/ land cover map reveals the spatial distribution of the various categories of land use/land cover over the study area. Figure 2, shows the classified land use/land cover map of the study area for the year 2003. The map reveals five (5) categories of land use/land covers; built-ups, cultivated land, grassland, bare surface and water bodies. The real extent of these classes reveal that the dominant class is forest cover which covers 573.52 km^2 (34.58%), this is followed by grassland areas with 535.52 km^2 (32.29%). This is seen scattered mostly at the north western, western and south western section of the map as well as the south west, farmland area covers 477.74 km^2 (28.80%) while built up areas on the other hand, occupies an area of 71.55 km^2 (4.31%), and the water body covering 0.29 km^2 (0.02%). The total land area is 1658.61 km^2.

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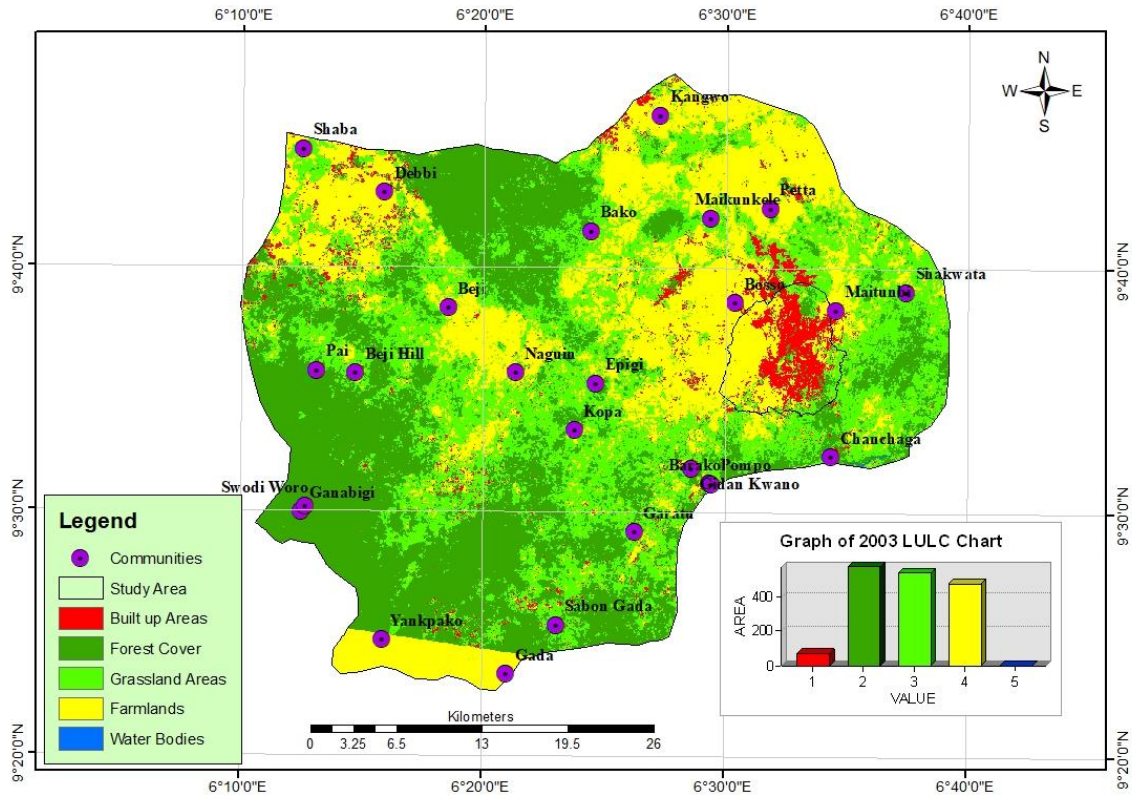

Figure 2: Classified 2003 LULC Distribution map Generated from Landsat 5

4.1.2 Analysis of 2013 land use/land cover classification for the Study Area

Figure 3, indicates the classified land use/land cover map of the study area for the year 2013. The map reveals five (5) categories of land use/land covers; built-ups, forest cover, cultivated land, grassland and water bodies. There were drastic changes in the various land use and land cover classes as some increase and other decreases. The areal extent of these classes reveal that the dominant class is grassland areas which covers an area of 711.67 km^2 (42.91%) in 2013, an increase of (8.33%). This increase in grassland can be attributed to high rate of deforestation that has taken place.

Farmland area covers 663.01 km^2 (39.97%) in 2013 while built up areas on the other hand, occupies an area of 71.55 km^2 (4.31%) in 2003 but increased to 166.55 km^2 (10.04%) in 2013, and the water body covering 0.29 km^2 (0.02%) in 2003, however increased to 3.82 km^2 (0.23%). Furthermore, there was a drastic change in forest cover. The forest decreased from 573.52 km^2 (34.58%) in 2003 to 113.59 km^2 (6.85%). This drastic change is attributed to deforestation and lumbering activities as a result of increased population in the study area.

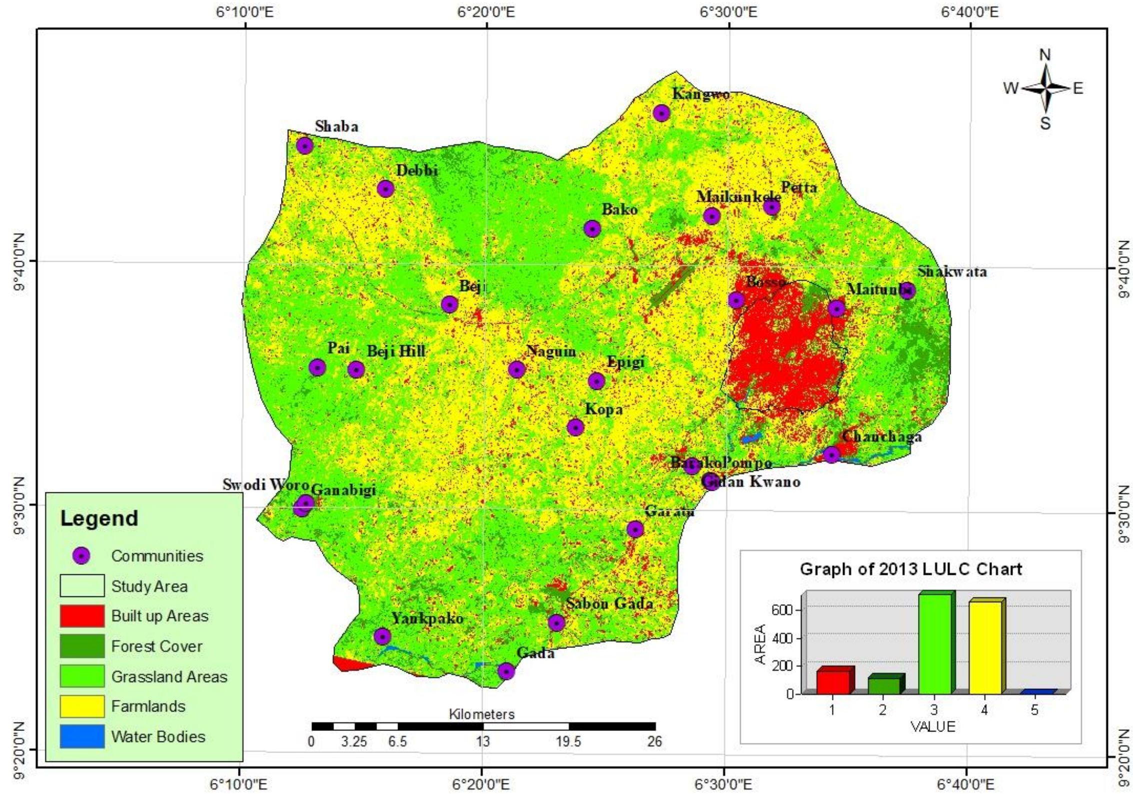

Figure 3: Classified 2013 LULC Distribution map Generated from Landsat 8 (OLI)

4.1.3 Analysis of 2023 land use/land cover classification for the Study Area

The areal extent of these classes reveal that the dominant class is still grassland areas although with some reduction, it covers an area of 711.67 km^2 (42.91%) in 2013 to 674.98 km^2 (40.70%) in 2023 a decrease of (2.11%).

This decrease in grassland can be attributed to high rate of urbanization and farming activities that has taken place. Farmland area covers 663.01 km^2 (39.97%) in 2013 but decreased to 582.76 km^2 (35.14%) in 2023 while built up areas on the other hand, occupies an area of 166.55 km^2 (10.04%) in 2013 but increased to 296.87 km^2 (17.90%) in 2023. Water body covering 3.82 km^2 (0.23%) in 2013 however increased to 5.14 km^2 (0.0.31%) in 2023. Forest cover. The forest decreased further from 113.59 km^2 (6.85%) in 2013 to 98.82 km^2 (5.96%) in 2023.

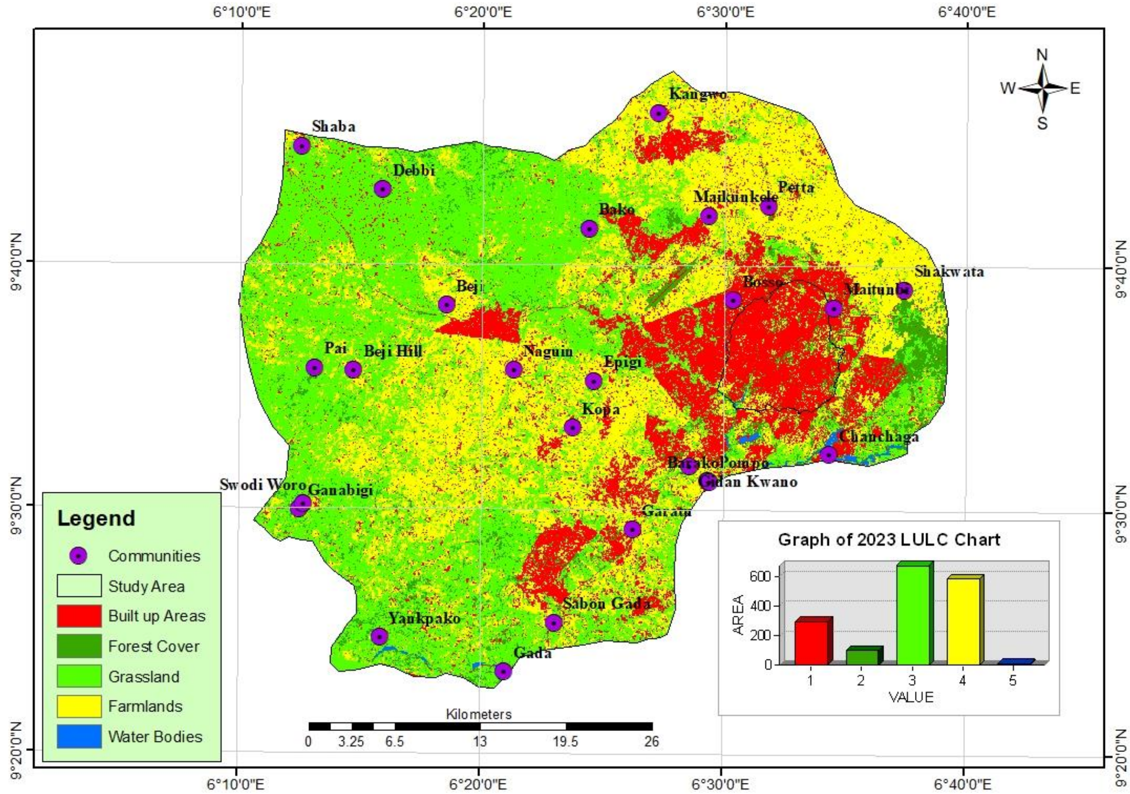

Figure 4: Classified 2023 LULC Distribution map Generated from Landsat 8 (OLI)

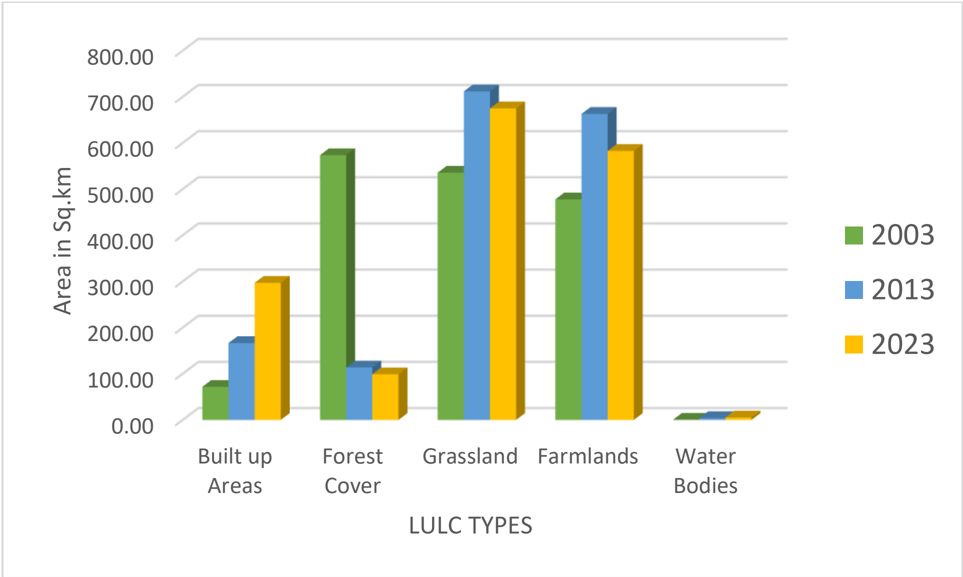

Figure 5: Comparative trend Chart

4.2 Analysis of Rainfall Distribution across the Study Area for 2003, 2013 and 2023

4.2.1 Analysis of Rainfall Distribution across the Study Area for 2003

The values of rainfall distribution were divided into five categories: low, secondary low, medium, secondary high and high classes which can also be regarded as the spatial variation in rainfall distribution across the study area. The classification represents the level of rainfall distribution. The value ranges from 1535.21mm – 1997.98mm. The deep blue color indicates high rainfall distribution areas while the light blue color represents low rainfall distribution areas for the year 2003 (Figure 6). The figure illustrates the image of rainfall distribution results which display the distribution of rainfall distribution values, and from their legends, the distribution of rainfall distribution variation is also shown.

Based on the classification, the very low class occupies an area of 2641.56 km^2 (15.71%), low class occupies 3348.90 km^2 (19.92%), moderate 2451.68 km^2 (14.58%), secondary high 3651.94 km^2 (21.72%) and high 4718.03 km^2 (28.06%) (Figure 6). Within the area and towards the eastern section of the map rainfall distribution is low when compared to the western and north eastern and other section of the map where the rainfall distribution is high.

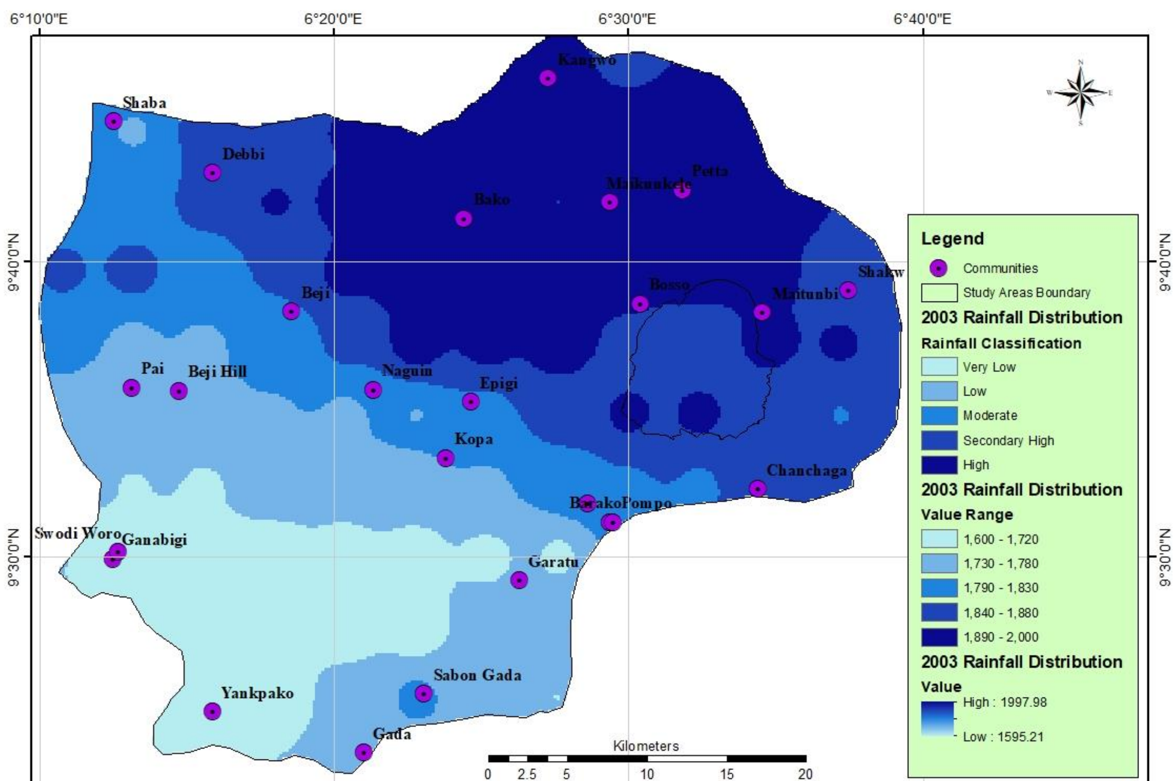

Figure 6: 2003 Rainfall Distribution Map Generated from Era 5 reanalysis Data

4.2.2 Analysis of Rainfall Distribution across the Study Area for 2013

Based on the classification, the very low class occupies an area of 5444.60 km^2 (32.42%), low class occupies 3832.85 km^2 (22.82%), moderate 3533.25 km^2 (21.04%), secondary high 2749.25 km^2 (16.37%) and high 1235.85 km^2 (7.36%) found majorly towards the eastern and southern section of the map (Figure 7). Rainfall distribution is low at the western section when compared to other section of the map where the rainfall distribution is high.

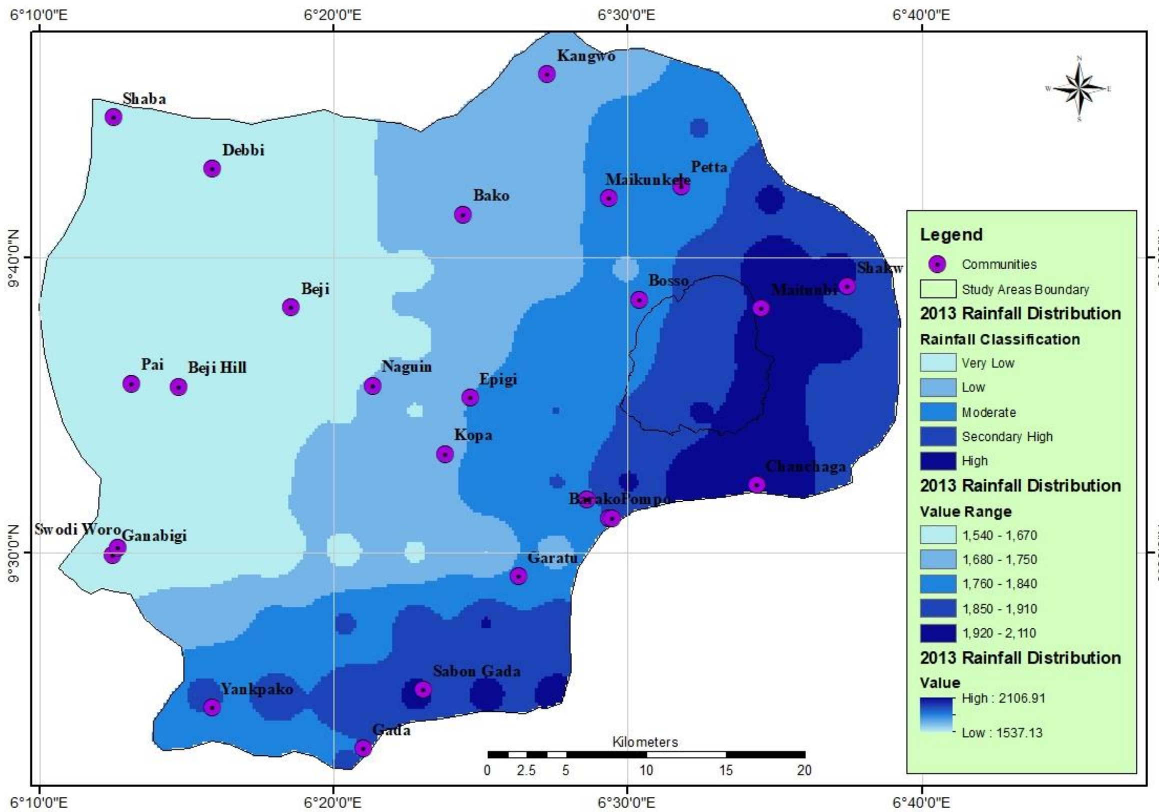

Figure 7: 2013 Rainfall Distribution Map Generated from Era 5 reanalysis Data

4.2.3 Analysis of Rainfall Distribution across the Study Area for 2023

Based on the classification, the very low class occupies an area of 285.53 km^2 (17.00%), low class occupies 563.36 km^2 (33.54%), moderate 563.96 km^2 (33.58%), secondary high 225.93 km^2 (13.45%) and high 40.81 km^2 (2.43%) found majorly towards the northern around beji and southern section of the map (figure 8). Rainfall distribution is low at the western section when compared to other section of the map where the rainfall distribution is high.

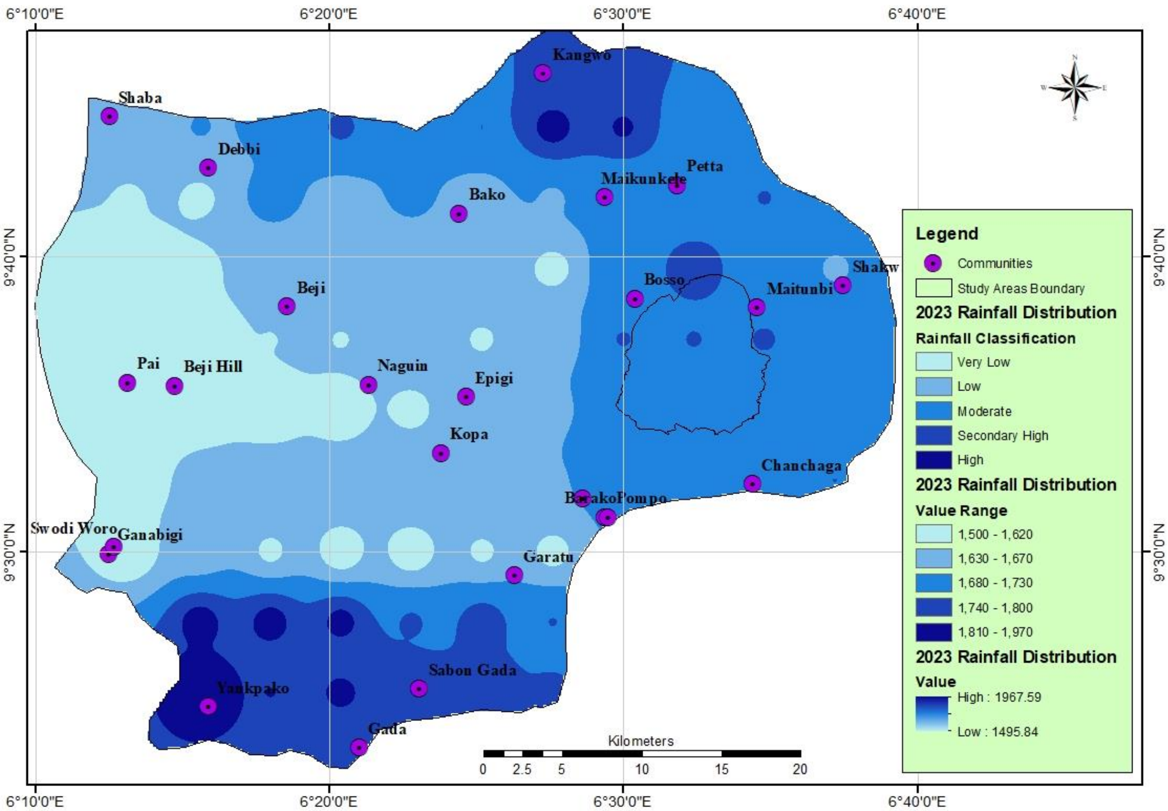

Figure 8: 2023 Rainfall Distribution Map Generated from Era 5 reanalysis Data

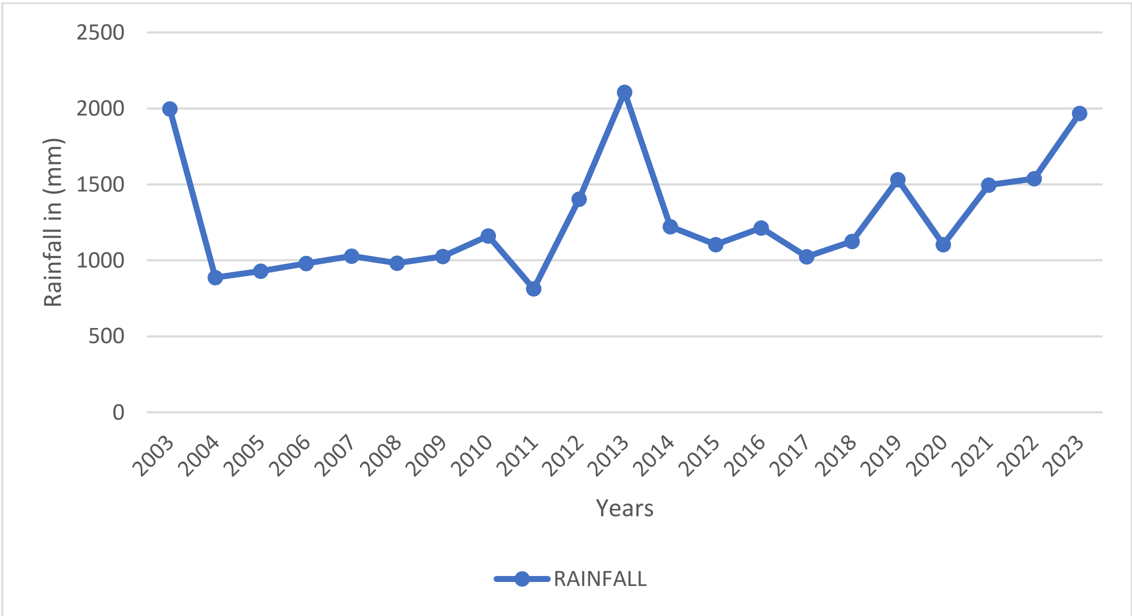

Figure 9: Annual Rainfall Trend between 2003 – 2023

Conclusion

The use of remotely sensed data and GIS techniques for flood analysis of study area in order to assess the flood disaster vulnerability has been demonstrated in this paper. In summary, the judicious application of Geographic Information Systems (GIS) in managing flood risks, particularly in high-vulnerability areas like the study area. GIS's unparalleled capacity to integrate and analyze diverse data sets, transforming them into practical, actionable insights, is crucial for safeguarding infrastructure and communities against flood risks. However, the essence of an effective flood management strategy goes beyond just technological implementations. It calls for a holistic approach that melds the precision of technology with the richness of community engagement, the foresight of dynamic modeling, and the synergy of interdisciplinary collaboration. Expanding on this, the role of GIS must be viewed as part of a larger tapestry of flood management efforts. It should be integrated with community-led initiatives, where local insights and experiences play a key role in shaping risk assessment and response strategies. This community-centric approach ensures that the solutions are not only scientifically sound but also culturally and socially relevant.

Recommendation

i. With the rapid influx of people from surrounding LGAS and States and high rate of building construction, there is every need to make sure that these developments should adhere to master plan.
ii. Automated mapping and analysis of the terrain of the State so as to generate data bank and a kind of master plan for flood disaster monitoring and management in the areaas well asgeneration of a comprehensive data and periodical reviews of all the communities that are vulnerable to flood in the state for quick decision making especially during flood disaster .

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