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MONITORING CHANGES IN PARTS OF THE GUINEA-SAVANNAH WOODLANDS, A CASE STUDY OF JIRAPA IN GHANA

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Abstract

Land use and land cover (LULC) in Ghana has undergone a lot of changes over the past years emanating from natural and anthropogenic activities. This study is a comprehensive analysis of LULC changes in parts of the Guinea-Savannah through an integrated approach of geospatial procedures. Multi-temporal satellite imagery data sets of four different years, 1990 (Landsat TM), 2000 (Landsat ETM+), 2010 (Landsat ETM+) and 2020 (Landsat ETM+) were analyzed. Built-up area, Agricultural land, Closed savannah vegetation, Open savannah vegetation and Water bodies were LULC categories delineated for Jirapa municipality. The Cellular Automata-Markov (CA-Markov) model was applied to predict the likely changes in LULC in 2030. The study revealed that the most dominant land cover type in the municipality is the Open savannah vegetation as it occupied averagely 45% of the total surface area. Built-up area increased in area coverage by 93% between 1990 and 2020. Agricultural activities, bushfires, deforestation, infrastructural development, and population growth are the main drivers of changes in Agricultural land, Open savannah vegetation, Closed savannah vegetation and Water bodies. The LULC prediction for 2030 showed that the Built-up areas would increase significantly in 2030 leading to a 6% reduction in Agricultural land in 2030.

Keywords: Built-up, Agriculture, land use, change, forecast, CA-Markov, prediction, population

INTRODUCTION

The Earth's surface and its natural ecosystem over the years have experienced rapid transformation due to the activities of humankind. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Service (IPBES) estimated that 75% of the earth's land surface has been affected by the activities of humankind and projected a 10% increase to 85% by 2050 (Scholes et al., 2018; Díaz et al., 2019; Allan et al., 2022). In Ghana, activities such as farming, lumbering, sand winning, and infrastructural development have caused the land cover to change continuously. For example, the cutting of trees for charcoal/firewood within the Upper West Region of Ghana has led to the depletion of the forest reserves and Jirapa Municipality is no exception (Agyeman et al., 2012; Korah et al., 2023). Peters (2019) asserted that these human activities have led to the transformation of the natural ecosystem, leaving behind only small scraps of the original ecosystem to survive. As such, about 60% of the ecosystem has undergone degradation in the past half a century (Scholes et al., 2018).

Developing nations such as Ghana mostly depend on available natural resources to satisfy their needs and sustain their economy. There is therefore a growing concern and interest in land use and land cover in Ghana. Appiah et al. (2015) observed that Ghana in recent decades has experienced significant levels of change in land use and land cover due to increasing economic activities, demographic factors, political activities, environmental forces as well as agricultural factors. Jirapa municipal district in Ghana over the years, has experienced increases in these drivers with their consequent effects on the environment and social setting.

Some important demographic factors experienced in the past decades by the Jirapa municipal district are the tremendous increase in the general population and urbanization. The Ghana Statistical Service (GSS) observed that in the past two decades, the municipality has seen a significant increase in the number of people living in the municipal district. The 2021 census showed a 3.3 % increase in population from 2010 (GSS, 2010; GSS, 2021). Accompanied by the increase in population, is increasing urbanization mostly noticeable in infrastructural development, economic activities and increase in urban population. For example, the 2021 census recorded that about 20.7% of the total municipal district population lived in urban centres (GSS, 2010; GSS, 2021). A direct effect of increasing population and urbanization is the increase in the demand for land and land resources for purposes of infrastructural development (causing excessive sand winning), economic activities, and agricultural activities.

The importance of Land Use and Land Cover (LULC) changes cannot be over emphasized as it has increased agricultural land thus leading to increase food production (Lahai et al., 2022). A significant proportion of the municipal population is engaged in agricultural activities for household subsistence and commercial purposes. The farmers are primarily into small-scale, family-operated agricultural activities due to problems of poor infrastructure, low technology, and financial availability. To increase productivity to meet the ever-rising demand for agricultural produce, the farmers resort to the extensification method rather than the intensification method. Extensification is a type of agricultural system that increases production by expanding the area under cultivation while reducing or maintaining aggregate input levels per unit area. In contrast, intensification raises production per unit area through more intensive practices. In West Africa, extensive agricultural system is comparatively the most often employed method of agricultural production (Erenstein, 2006). This can be attributed to the comparatively low population density of rural agrarian areas, low capital resource endowments and market constraints. According to Houssou et al. (2016), agricultural production in Ghana has been increasing gradually, with the gain mostly attributable to an increase in the cultivated area rather than a productivity improvement. Jirapa municipality generally practices the extensive method in agriculture with most farmers expanding their area of cultivation to increase production. It is also observed that farmers engage in fallow practices for previously cultivated lands to regain their nutrients. This has led to more vegetation cover being cleared through the slash and burn method, overgrazing, and deforestation.

Consequently, deforestation in the district has been on the rise over the years not only due to agricultural activities but also through increase in demand for trees for firewood and charcoal. A significant number of households in the municipality depend mainly on firewood as their source of energy for carrying out their domestic and commercial activities. Beer brewing, locally known as pito brewing, is a commercial activity in the area which uses a lot of firewood in its production process. Lumbermen are employed to cut down small and medium-sized trees in the area for the pito brewers while the big trees serve charcoal-burning purposes.

Controlled or uncontrolled bush burning is also an environmental problem that is faced by many districts in the Savannah ecosystem including Jirapa municipal district. It is observed that during the dry season, most of the environment is burnt for reasons such as farming, protection from harmful animals (predators), and burning out of jealousy (Yahaya and Amoah, 2013). Bush fires may also be caused by careless smokers, hunters, and bee tapers. Bush fires burn down farm produce that is yet to be harvested and economic trees. For example, economic trees such as Shea, and dawadawa are mostly affected because their fruiting period is in the dry season. Yahaya and Amoah (2013) asserted that bushfires have therefore played a damaging role in agricultural production and in accelerating environmental degradation, especially in the fragile Savannah ecosystem.

LULC information and knowledge are important for proper planning, management, and regulation of natural resource usage (Bakr, et al., 2010). LULC data over the years are mostly provided with the use of Remote Sensing (RS) and Geographic Information System (GIS) techniques and technology. Land use and land cover change (LULCC) studies are useful in understanding the relationship between the natural environment and human activities in a particular study area. LULCC studies are mostly localized and place-specific as they vary depending on geographical location, culture, traditions, purpose, as well as climate conditions.

Land use and land cover (LULC) are often used interchangeably, but their actual meaning is not synonymous (Peters, 2019). This implies that the two are transposable terms; however with different connotations in land change science (Alam et al., 2019). Land cover describes the natural and anthropogenic features that can be found on the earth's surface (Kamwi et al., 2018). Examples include vegetation, built-up areas, wetlands, deserts, water bodies, ice, biota, etc. Land use, on the other hand, describes the activities that occur on the land surface and represent the current usage of resources and properties found on the land surface (Kamwi et al., 2018). It reflects human activities such as industrial zones, residential zones, agricultural fields, grazing, logging, mining, etc. The land cover is most obvious in the field compared to land use, which is inferred from the land cover. Fonji and Taff (2014) observed that in land change science, which often involves remote sensing and geographic information system, land use and land cover are often used together to avoid ambiguity in the final result.

LULC has been changing since humankind started to manage its environment (Harris and Ventura, 1995). These changes can be broadly grouped into two categories, namely conversion, and modification (Oumer, 2009). Conversion refers to changes from one land cover or land use to another, while modification involves maintenance of the land cover or land use type in the face of changes in its attributes (Oumer, 2009). Therefore, LULC change can be defined as any physical, biological, or chemical change attributable to the management of the land cover.

This study aims to identify the trend of LULC changes and to understand the role that anthropogenic activities play in providing information on the LULC change system of the Jirapa municipality; as well as to identify the impact of such activities on the natural ecosystem. This would help the Department of Town and Country Planning at the municipal district assembly, make effective planning and management decisions on the development of infrastructure in the district. It would also help in the sustainable management and utilization of land and land resources in the municipality. The data obtained from this research for example can be used in the management and utilization of water resources, forest resources, soil, and infrastructure development planning.

The research focuses on the Jirapa municipal district and spans three decades with a prediction of LULC change in the next decade. The study identifies LULC forms in the Jirapa municipality and makes projections to the year 2030. This is in support of Aduah and Aabeyir's (2012) study that recommended that land cover dynamics be studied outside the Wa municipality, and in different parts of semi-arid regions in Ghana, for the purpose of environmental monitoring and to track general land cover changes.

Kamwi et al. (2018) proposed that drivers of LULC change are multifaceted and they emanate from the interaction between humans and the environmental systems, including social, economic, political, and institutional factors associated with a particular region. Mallupattu and Reddy (2013) identified the main reasons behind LULC change as rapid population growth, rural-urban migration, reclassification of rural areas as urban areas, lack of valuation of ecological services, poverty, ignorance of biophysical limitations and use of ecological incompatible technologies, etc. Hence, local human activities which mostly express the drivers of LULC change can be determined by measuring the rate and type of changes with analysis of relevant sources of data such as demographic profiles, household characteristics, policy documents on land resource management, and administration (Ali, 2009).

Kamwi et al. (2018) identified drivers of LULC change in the Zambezi Region of Namibia, ascribing the changes to proximity to roads and settlements, population density, and fire return periods. Similarly, studies in the northern part of Ghana have shown that livestock rearing, bushfires, forest accessibility by road, farm practices, and population growth are the important drivers of LULC change in the area (Agariga et al. 2021). In terms of demographic factors, the northern part of the country is experiencing rapid population growth that exceeds the carrying capacity of the large Savannah land cover (Weeks et al., 2017). Coulter et al. (2016) estimated that about 62% of the landscape in the northern belt of Ghana serves as agricultural land. Intensifying agricultural activities to meet growing demands for food by the ever-increasing human population, results in significant changes in the vegetation cover in the northern part of Ghana (Kusimi, 2008).

Changes in LULC may affect the capacity of the ecosystem to sustain livelihoods and provide services such as climate regulation, biodiversity maintenance, erosion control, food production, etc. (Kamwi et al., 2018; Agariga et al., 2021). One of the significant challenges facing the world today relates to the management of the transformation of the earth's surface (Ali, 2009). Evaluating LULC changes is therefore imperative to overcoming environmental problems and issues at the regional and national levels (Alam et al., 2019). These challenges collectively add up to global environmental changes that influence various components of the earth (atmospheric system) with adverse effects of biodiversity loss, desertification, climate change, destruction of wetlands, unregulated development, etc. (Fonji and Taff, 2014). This implies that from the local level to the global level, LULC changes provide information needed in the formulation of policies regarding economic, environmental, and demographic issues (Mariwah et al., 2015) aimed at developing proper coordination and management strategies for land use (Agariga et al., 2021). LULC change studies sort to explain five major questions including; where change is occurring, the types of transformation happening, the rate or amount of change, what land cover types are changing, and the driving forces causing the change (Alam et al., 2019).

Geographic information system (GIS) and Remote sensing (RS) techniques provide the effective tools and information needed for analyzing land use and land cover changes in a particular region as well as monitoring and managing natural resources (Addae and Oppelt, 2019). RS and GIS technology provides the opportunity for researchers to collect, process, and analyze data from a particular study area without having to be physically present in the location. It has also become very easy to perform periodic and precise LULCC analysis of any place on the earth's surface. The periodic and precise analysis of LULCC is important in understanding the relationship and interactions between the natural environment and humankind. Past studies have shown the use of GIS and RS techniques in land use and land cover dynamics as well as change detection analysis (Asempah, Sahwan, and Schütt, 2021; Koranteng et al. 2020; Dadson 2016, etc.). Thus, in recent decades, GIS and RS data have been the predominant and primary sources of data extensively used in LULCC studies across the world.

The various aspects of LULC change reliably are measured through the use of Geographic Information System and Remote Sensing technology (Alam et al., 2019). Remote sensing and Geographic information system currently have the most reliable tools for monitoring and detecting varied spectrally sensitive changes on the earth's surface. Remote sensing imageries with variable resolutions in combination with the use of different descriptive models provide the opportunity to obtain past, present, and future land use and land cover patterns (Alam et al., 2019). Monitoring and analysis of LULC change require a substantial amount of data about the earth's surface. Previously, in the absence of Remote Sensing, such data on LULC change could be generated primarily through conventional survey techniques which are costly, tedious, time-consuming, and also impractical for monitoring dynamic changes over a short period (Mariwah et al., 2015). Remote Sensing Satellite images serve as excellent sources of data from which LULC information and changes can be extracted, analyzed, and simulated efficiently (Mariwah et al., 2015). Due to the availability, range, spatial resolution and scope of free Landsat images, this study chose to use Landsat data in assessing LULC changes in Jirapa Municipality.

Geographic information System provides a flexible environment for entering, analyzing, and displaying digital data for the identification of LULC features from various sources (Stemn and Agyapong, 2014). GIS provides a model for illustrating trends in land use and land cover changes supported by adequate statistics. Thus, the integration of Remote Sensing (RS) and Geographic Information System (GIS) has the potential of providing accurate and timely geospatial data and information on LULC changes in a particular region.

STUDY AREA

The Jirapa Municipality (Fig. 1) was established by Legislative Instrument (L.I.) 1902 and is one of the eleven districts in the Upper West region of Ghana. It was formerly part of the then-larger district called Jirapa-Lambussie District in 1988; of which the northern part of the district was carved out to form the Lambussie-Karni District on 29th February 2008 with the remaining part renamed as Jirapa district (MoFA, 2019). On 15th of March 2018, the Jirapa district was upgraded to a Municipality status backed by L.I. 2278 with Jirapa as the district capital.

The Municipality is located in the North Western Corner of the Upper West region of Ghana (Fig. 1). It lies approximately between Latitudes 10˚20'0"N to 10˚50'0"N and between Longitudes 2˚20'0"W to 2˚50'0"W (Fig 1). The municipality shares administrative boundaries with the Nadowli district to the South, the Lawra district to the West, the Lambussie-Karni district to the North, and the Sissala East to the East. According to the Ghana Statistical Service, the Municipal has approximately 1,166 km2 of land area which represents 6.3% of the land area in the Upper West Region.

Jirapa municipality is generally dominated by sandy and loamy soils with tiny patches of alluvial soil along the valleys of the Black Volta River tributaries. This alluvial soil is suitable for rice production. Areas characterized by sandy loam soil are prone to severe sheet erosion and gully erosion. The land surface undergoes erosion due to the surface run-off that occurs in the raining season. This has led to the silting of dams and loss of soil fertility in the area. This notwithstanding, the sandy loam soil is quite productive in groundnut farming. The available vast fertile land in Samboro, Tuggo, and Han supports large-scale agricultural production. The main crops produced in these areas are cereals (Maize, Millet). The municipality is also characterized by many gravel pits that were created as a result of road construction. A geological mapping campaign carried out by the Ghana Geological Survey Authority (GGSA) in 1998 established that the extensive Birimian (metavolvanics, metasediments and Granitic intrusive rocks) found around Yahga and Jirapa store significant amounts of gold. These rocks owing to their pervasive developed secondary structures serve as major water reservoirs for borehole sinking in the area. In recent times, there has been a rise in small-scale mining in the region and the Jirapa Municipality is one of the districts with a high number of illegal mining-related activities.

The municipal district is located within the tropical continental climate with a mean annual temperature ranging from 28°C to 31°C. The municipality experiences only a single raining season from May-October. This rainy season is mostly induced by the southwest monsoon winds which have an intensity of about 1000 mm to 1100 mm per year. The humidity is about 70-90 % in the raining season but falls to about 20 % in the dry season. Increased effect of climate change has resulted in irregular rainfall patterns in the area making it very difficult for farmers to predict and plan for the cropping year. In November, the municipality experiences cold, dry, and dusty air (Harmattan) as a result of the tropical continental winds blowing from the North-Eastern (Sahara) part of the country.

The vegetation of the municipality is guinea savannah woodland with light undergrowth and scattered trees. Some major trees found in the area include Shea, Dawadawa, Baobab, Neem, and recently Cashew. There is no major forest reserve in the municipality except for some isolated pockets of forest that are along the Black Volta in Samboro, Tuolong, and Yagbetuolong. The municipality faces significant destruction of its natural

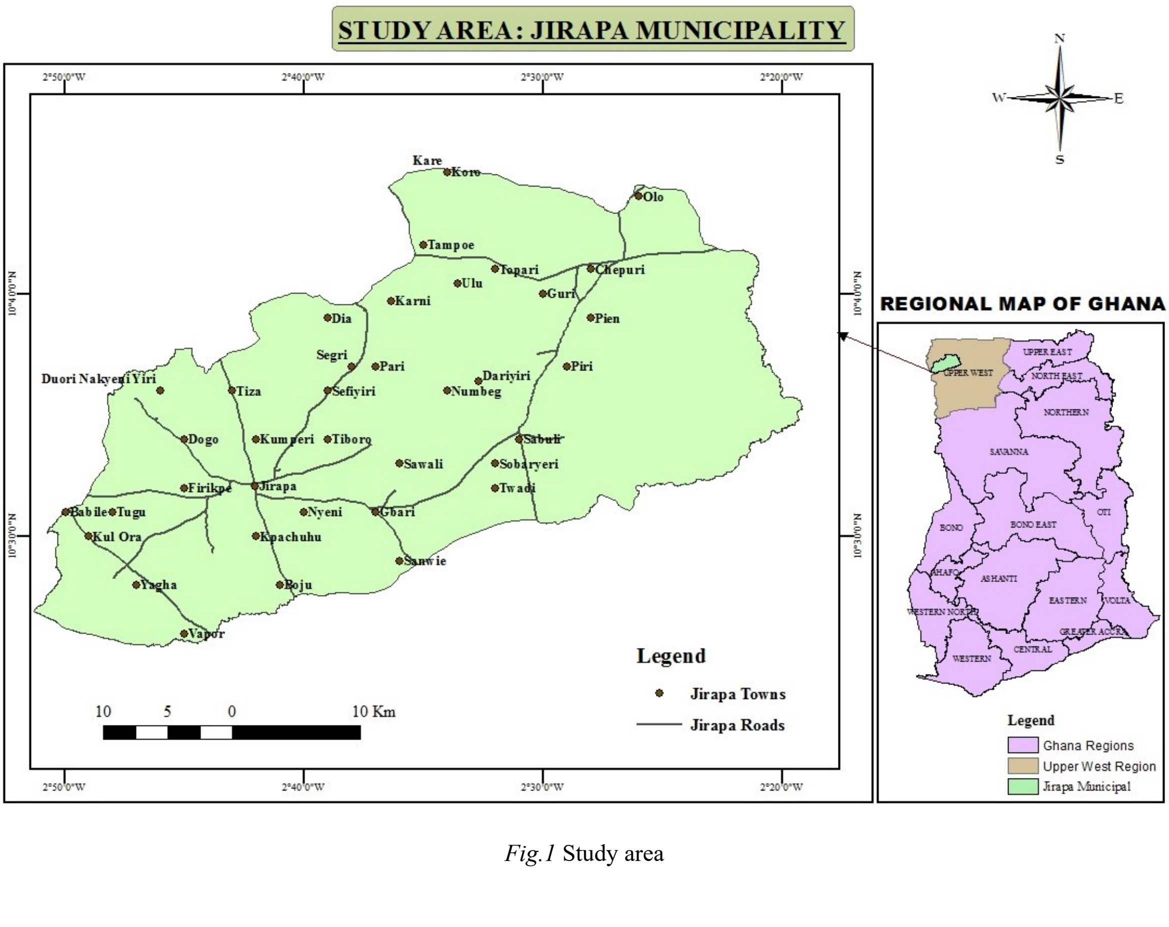

Fig.1 Study area

vegetation due to anthropogenic activities such as bushfires, sand winning and charcoal burning.

The municipal has a total population of 91,279 which is about 10.1% of the Upper West region population (901,502 people). The distribution in terms of gender comprises 52.9% females and 47.1% males (GSS, 2021). According to the 2021 Population and Housing census, the municipal population is largely dominated by rural dwellers; about 79.3% of the total municipal population are living in rural areas such as Koro, Vaper, and Tizza. This implies that 20.7% of the total population live in urban areas such as Jirapa, Karni, Sabuli, Pari, and Ulu. The urban area here is measured according to the standard requirement of 5,000 people and above.

The economy of the municipality is largely characterized by agricultural activities, agro-processing, and other small-scale manufacturing activities. Agriculture which engages about 67.1% of the people remains the major economic activity in the municipality. There is also a high level of commerce in mostly agricultural goods and services. Pito brewing is an economic activity that is specifically engaged in by the females in the municipality.

METHODS

The study was based on the use of time series of satellite Landsat images –Thematic Mapper ™ and Enhanced Thematic Mapper Plus (ETM+) as remote sensing data acquired in the years 1990, 2000, 2010, and 2020 (Table 1). The remotely sensed satellite images were obtained from the Earth Resources Observation and Science (EROS) of the United State Geological Survey (USGS) website (https://earthexplorer.usgs.gov/). The cloud cover was set below 10% to enhance the accuracy of the result obtained and to minimize the atmospheric effects. Table 1 shows the summary of the data obtained.

The satellite images were obtained in October and November to minimize errors that might occur as a result of differences in seasons. Other data used in this study include Ghana vector data on roads, towns, and district boundary.

Image pre-processing

The multi-temporal images were processed geometrically and radiometrically to correct errors emerging from sensors, atmospheric effects, and the earth's curvature. This allows for the correction of errors in measured reflectance due to changes in the electromagnetic radiation recorded by the Landsat 5 and 7 sensors. The Gap-fill extension in the Envi.5.3 software was used to remove scan lines from the satellite images which may be caused by errors from the sensors during scan time. As shown in figure 2, there is a clear distinction between data before gap-fill (a) and after gap-fill (b).

It must be noted that all four Landsat data were subjected to the scan line removal process through the Gap-fill extension. Before classification, it is important to perform radiometric calibration, which helps to enhance image reflectance levels. This was also carried out in the Envi 5.3 software. Figure 3 shows the image before (i) and the image after calibration (ii). The calibrated images where loaded in ArcMap for further processing and classification. To be able to classify the images with higher precision, the Landsat bands were stacked using the band composite tool in ArcMap. This composite band allows for the band combination to be changed to reflect the various LULC classes.

The various Landsat images downloaded from USGS explorer website were already ortho-corrected, hence there were no georeferenced done on the images. However, since the study area is smaller than the Landsat scene downloaded, sub-setting was done to limit the image to the boundaries of Jirapa Municipality. This was

Table 1 Landsat TM/EMT+ Data

Landsat Product	Date Acquired	Path/Row	Spatial Resolution	Source
Landsat TM 5	12 October,1990	195/053	30	USGS
Landsat 7 ETM+	31 October,2000	195/053	30	USGS
Landsat 7 ETM+	12 November,2010	195/053	30	USGS
Landsat 7 ETM+	22 October, 2020	195/053	30	USGS

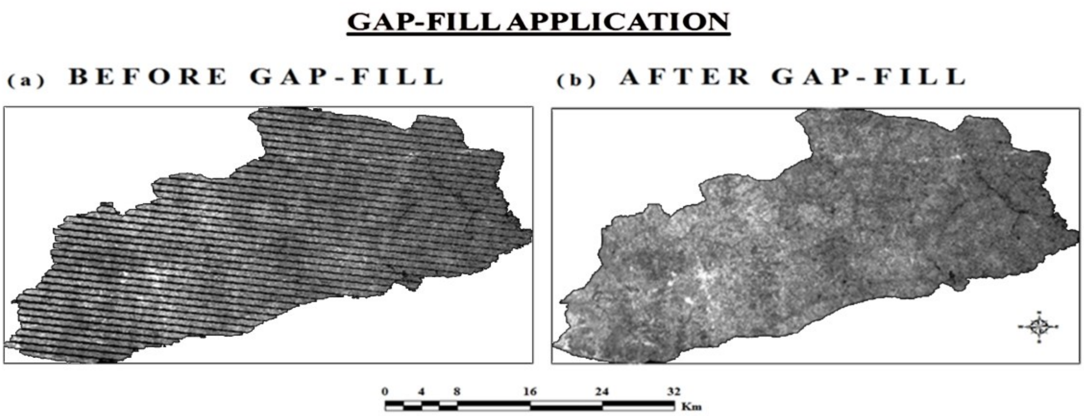

Fig.2 Gap-fill analysis showing differences in image output

done using the clip tool in ArcMap Software where the shape file of the Jirapa municipality was used to subset the Landsat scenes to the study area.

Image classification

The supervised classification method was used in this study. The maximum likelihood classification algorithm which classifies images based on the covariance and variance of the spectral response patterns of pixels was used in the classification. The image was classified into five (5) classes namely Built-up area, Agricultural land, Open savannah vegetation, Closed savannah vegetation, and Water bodies (Table 2).

A layout procedure in ArcMap 10.8 was followed to generate the Error and Confusion matrix for the four classified images. Google Earth Pro was used to pick the validation points for the four images. Ground truth points also known as reference points were identified on the 1990, 2000, 2010 and 2020 classified images. In ArcMap, these points were converted to a KML file which was subsequently uploaded into Google Earth Pro, with 100 validation points.

In LULC studies, the Kappa Coefficient and Overall Accuracy are mostly the essential determinants used to ascertain the reliability of classified Landsat images. Below is the calculation for the overall accuracy and kappa coefficient. The calculation for the Producer Accuracy and User Accuracy is done base on equation 1.

The Kappa coefficient is more scientific than the overall accuracy which is simply calculated by dividing the total number of correctly classified pixels by the total number of reference pixels (actual observation). The kappa coefficient is achieved with equation 2.
The producer accuracy and the user accuracy of the classified images was calculated using the formulas in equations 3 and 4 respectively.

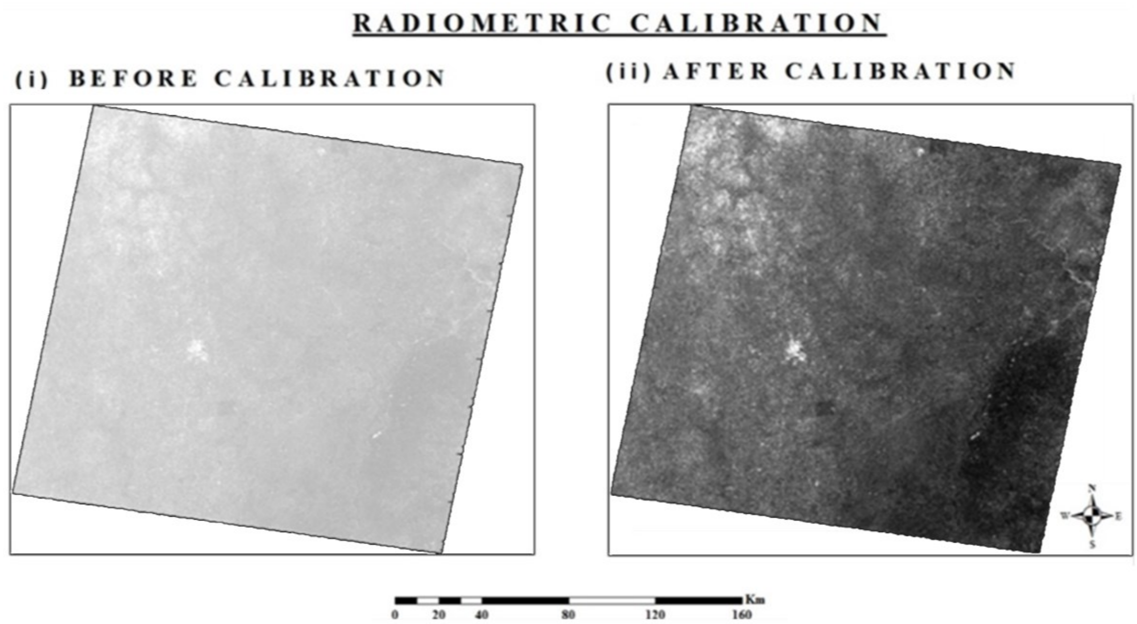

Fig.3 Calibration output showing difference in imagery

Table 2 Land Use and Land Cover Classes

Classification classes	Description
Built-up Area	The built-up area consists of all the physical infrastructure that can be found in the area. They may include houses, market centres, roads, etc.
Agricultural Land	Agricultural land is made up of the available land used for the production of food crops and animals. For this Land use and Land cover change analysis, agriculture and bare soil classes are merged into the Agriculture Land class. This is because bare soil in Jirapa generally represents agricultural land (fallow or recently harvested).
Open Savannah Vegetation	This vegetation is mostly characterized by grassland with few trees widely disperse in the area. The vegetation cover is generally grassed with few isolated trees.
Closed Savannah Vegetation	The closed savannah vegetation is a less dense forest area that is made up of grasses and trees. Thus, its vegetation cover is denser with trees and grasses compared to the open savannah vegetation.
Water Bodies	Water bodies comprise all the water sources such as lakes, valleys, rivers, dams, etc. in the area. The study area contains a significant number of valleys leading into the Black Volta.

$$Overall\ Accuracy = \frac{Total\ Number\ of\ Correctly\ Classified\ Pixels}{Total\ Number\ of\ Reference\ pixels} \times 100\% \quad (1)$$

$$Kappa\ Coefficient(K) = \frac{TS \times TCS - \sum(Column\ Total \times Row\ Total)}{TS^2 - \sum(Column\ Total \times Row\ Total)} \quad (2)$$

where TS is the Total Sample and TCS is the Total Correctly Classified Sample

$$Producer\ Accuracy = \frac{Number\ of\ correctly\ Classified\ Pixels\ \in\ each\ category}{totalNumberofReferencedPixels \in thatcategory} \times 100\% \quad (3)$$

$$User\ Accuracy = \frac{Number\ of\ correctly\ Classified\ Pixels\ \in\ each\ category}{total\ Number\ of\ Classified\ Pixels\ \in\ that\ category} \times 100\% \quad (4)$$

Change detection

Lunetta and Elvidge (1999) put forward two change detection techniques namely, post-classification and pre-classification techniques. This research used the post-classification technique of change detection, which is based on the differences between classified images of different dates. The method relies on the accurate registration of images to the same coordinate and projection systems (Aduah and Aabeyir, 2012). Change detection for 1990-2000, 2000-2010, 2010-2020 and 1990-2020 was performed after the accuracy assessment proved the reliability of the classified images.

Forecasting

The CA-Markov model was used to produce the 2030 LULC prediction map. QGIS 2.18.24 Molusce plugin which was designed to analyse, model and simulate LULC changes was used throughout the process. The Molusce plugin allows for analyses of LULC changes between different time periods, model LULC transition potential and simulate future LULC changes. The prediction map was obtained through five steps/modules with the first step involving the Input module that entails images of the 2010 and 2020 LULC maps with the variable input being distance from roads and distance from towns. The second step is the Area Change analysis which computes the changes between the two LULC maps loaded as the input module to produce the transition matrix and LULC change map are produced at this stage. In the third step, the Artificial Neural Networks (ANN) method which gives a good transition potential, is employed for modelling. Simulation is the fourth step which involves the Cellular-Automata (CA) Markov model to produce the 2020 and 2030 LULC map. The last step is the Validation step, which is important to determine the reliability and overall accuracy of the maps and statistics generated. The 2020 LULC predicted map was loaded alongside the actual 2020 LULC map produced. The validation involves the calculation of the kappa statistics (standard kappa, kappa histogram and kappa location). A strong kappa, greater than 0.80, validates the reliability of the model and accuracy level (Gemitzi, 2021). Figure 4 below indicates the data processing workflow of the study.

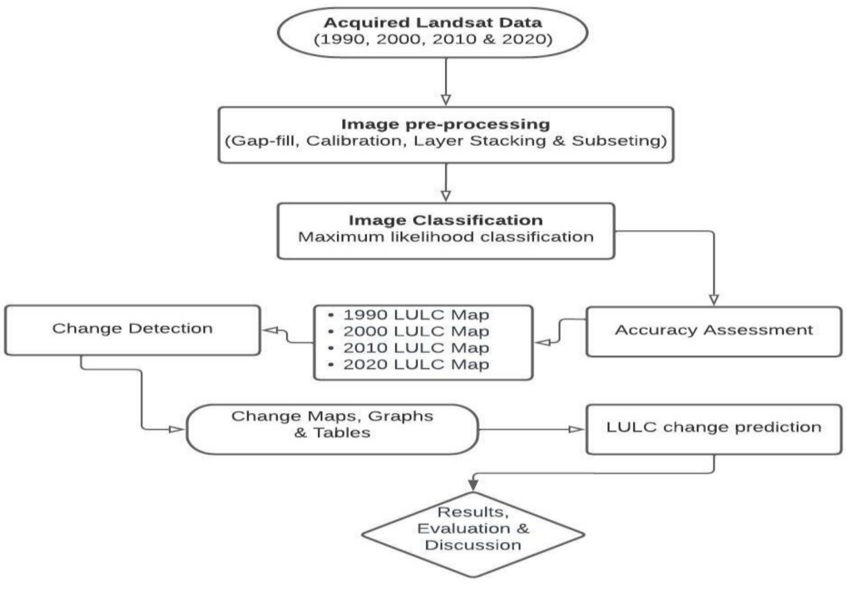

Fig.4 Data processing workflow

RESULTS

Land Use and Land Cover Maps of Jirapa Municipality.

1990 LULC Map

In 1990, Opened Savannah Vegetation is the most dominant LULC type in the Jirapa Municipality (Fig. 5) with a surface area of 769.2 km^2. This represented 65% of the surface area of Jirapa Municipality. The second dominant LULC type was the Built-up area which represented 14% and covered a surface area of 170.9 km^2 as shown in figure 6 The Agricultural Land was the next dominant LULC type in the municipality with landmass coverage of 164.7 km^2, representing 14% of the surface area. The Closed Savannah Vegetation occupied 81.4 km2 of the landmass (7% of the surface area). Water Bodies occupied 1.0 km^2 of the surface area representing 0.085% of the land surface. Figure 5 shows the distribution of the various LULC classes identified in the study in 1990 while figure 6 is a pie chart representation of the LULC types of Jirapa municipality for 1990.

2000 LULC Map

In 2000, Opened Savannah Vegetation remained the most dominant LULC type in Jirapa Municipality (Fig. 7). The Opened Savannah Vegetation increased in surface area to 804.3 km^2 representing 68% of the total landmass. Built-Up Area also saw an increase to 187.8 km^2 representing 16%. The Agricultural Land reduced in area coverage to 160.1 km^2 representing 13%. Closed Savannah Vegetation recorded a significant reduction as it covered 29.7 km^2 representing 3% of the total landmass. Water Bodies in the municipality registered a gain in size to 5.5 km2 represented 0.46%. Closed savannah vegetation is mostly along the water bodies in the district as shown in figure 7. A reduction in the closed savannah vegetation led to the exposure of more water bodies hence the increase in coverage of water bodies in 2000 (Fig. 8).

2010 LULC Map

Figure 9 revealed that Opened savannah remained the dominant LULC type even though it reduced in surface area coverage to 632.8 km^2 representing 53% of the total landmass. Agricultural land became the second most dominant LULC type in the municipality with an area of 300.3 km^2 representing 25% of the total landmass. Built-Up Area saw an increase in the coverage area to 204.4 km2 representing 17%. The Closed Savannah Vegetation increased and covered an area of 40.5 km^2 representing 4%. Water Bodies increased in coverage to 9.4 km^2 representing 1% of the surface area of Jirapa municipality (Fig. 10).

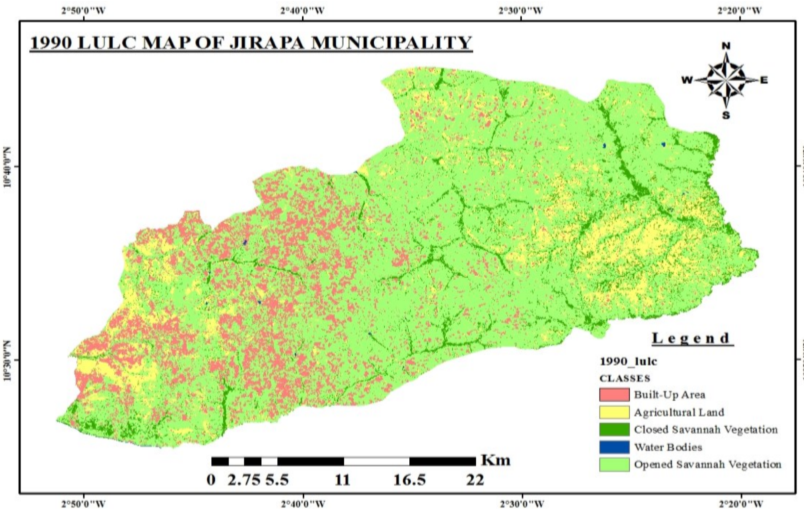

Fig.5 Classified Landsat TM 1990 image of Jirapa Municipality

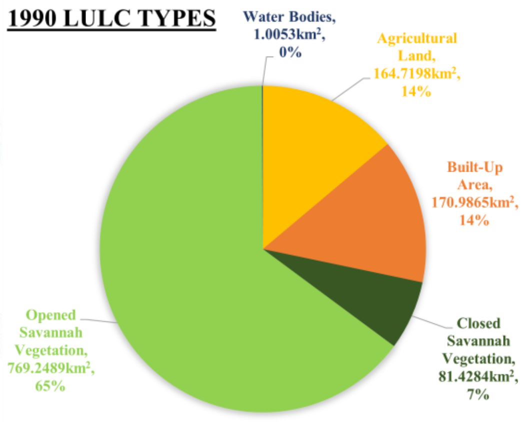

Fig.6 LULC types in Jirapa Municipality in 1990

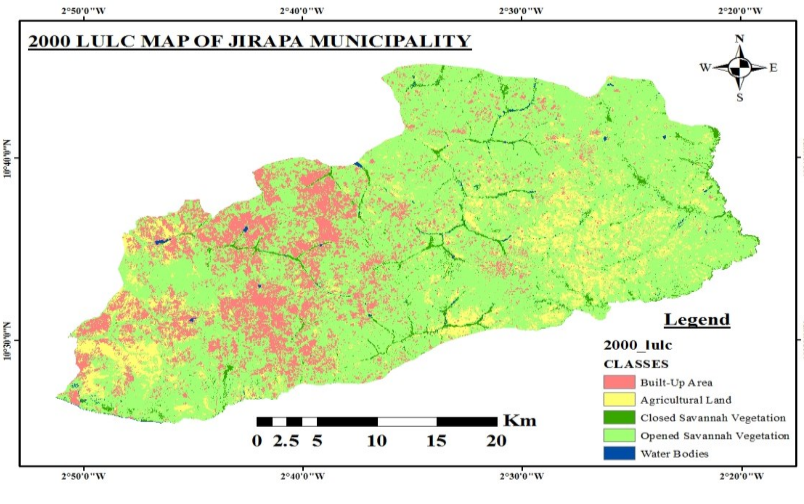

Fig.7 Classified Landsat ETM+ 2000 image of Jirapa Municipality

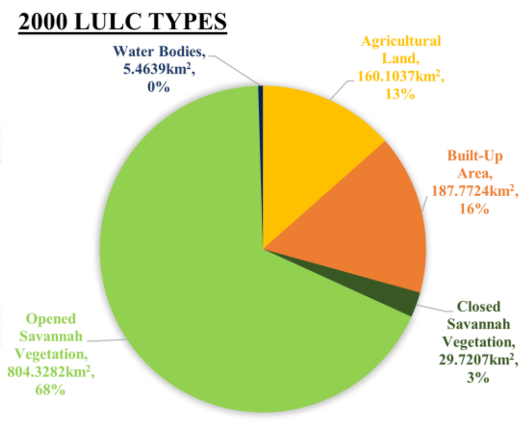

Fig.8 LULC types in Jirapa Municipality in 2000

LULC Change Detection in Jirapa Municipality

The results and discussion of the change detection are presented in table 3. The Class total (Row) represents the total area covered by the LULC types for the initial state (year) while the Class total (column) represents the total area covered by the LULC types for the Final state (year). The Class changes are the total change a LULC type recorded and finally, the image difference shows whether there has been any change in coverage of the LULC type. A positive and negative value represents an increase and decrease respectively in the area covered by the particular LULC type.

From 1990 to 2000, Agricultural Land that remained Agricultural land covered 69.3 km^2 while 92.5 km^2 of agricultural land in 1990 changed to other LULC types. About 88% of the change in agricultural land was to Open Savannah vegetation as Open Savannah vegetation gained 81.0 km^2 from agricultural land. 11.1 km^2 of Agricultural land was converted to Built-up areas. The remaining change was to Water bodies and Closed Savannah vegetation which recorded 0.3 km^2 and 0.1 km^2 respectively. The difference in agricultural land is -6.4 km^2 implying a reduction in the agricultural land from 1990 to 2000 (Table 4).

Built-up area that remained built-up was 79.3 km^2 while a total of 89.4 km^2 changed to other LULC forms. Out of this total change, Opened Savannah vegetation gained 78.2 km^2, agricultural land gained 10.9 km^2, Water bodies gain 0.24 km^2 and Closed Savannah vegetation gained 0.06 km^2. The image difference for the Built-up area is 25.8 km^2 implying an increase in the Built-up area from 1990 to 2000.

Closed Savannah vegetation experienced a total change of about 58.5 km^2 with 16.9 km^2 remaining same. Out of the total change, Open Savannah gained most of the change with 51.4 km^2 while 5.1 km^2, 1.1 km^2, and 1.0 km^2 were gained by Agricultural land, Water bodies and Built-up area respectively. Closed Savannah vegetation decreased within the period as the image difference is -47.5 km^2.

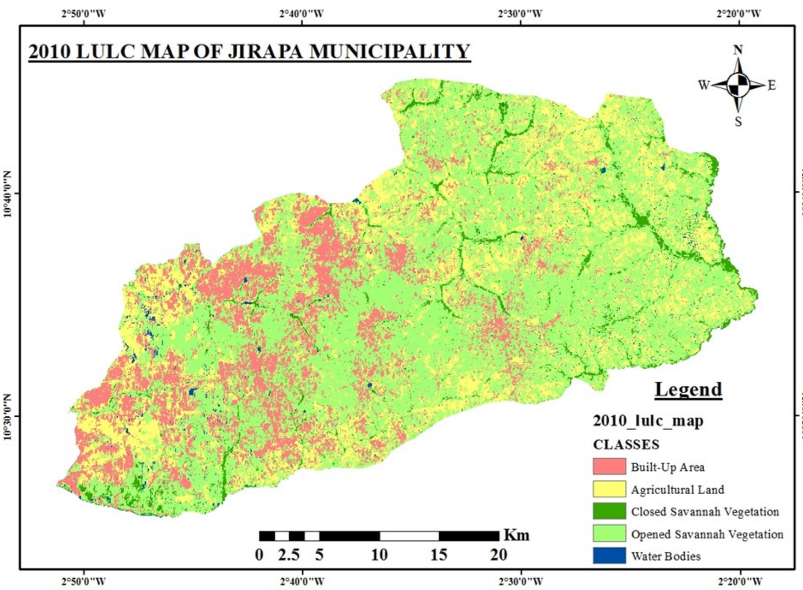

Fig.9 Classified Landsat ETM+ 2010 image of Jirapa Municipality

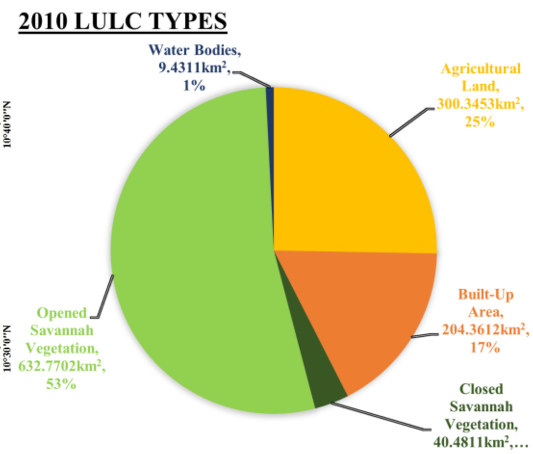

Fig.10 LULC types in Jirapa Municipality in 2010

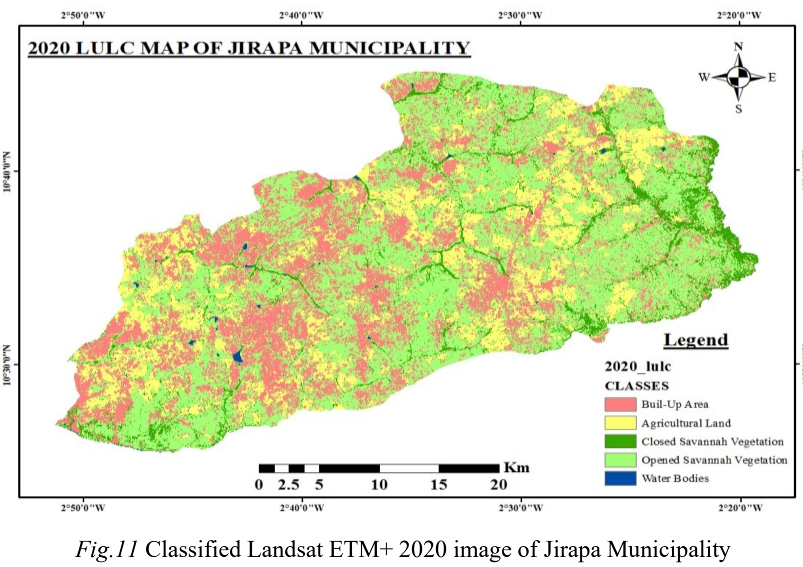

Fig.11 Classified Landsat ETM+ 2020 image of Jirapa Municipality

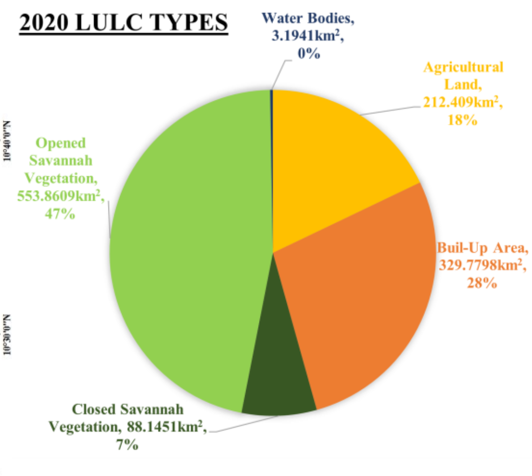

Fig.12 LULC types in Jirapa Municipality in 2020

Table 3 Accuracy Assessment for 1990, 2000, 2010 and 2020 Classification

	1990		2000		2010		2020	
Land Use/Cover	Reference Totals	Classified Totals	Reference Totals	Classified Totals	Reference Totals	Classified Totals	Reference Totals	Classified Totals
Built-Up Area	10	15	13	20	17	21	17	22
Agricultural Land	30	22	40	24	34	22	32	23
Closed Savannah Vegetation	16	23	13	17	13	17	15	18
Water Bodies	11	12	11	16	11	19	17	17
Opened Savannah Vegetation	23	18	23	23	25	21	19	20
Overall Accuracy	0.84		0.74		0.77		0.88	
Kappa Coefficient	0.80		0.67		0.71		0.85	

Table 4 Change Matrix of LULC in Jirapa Municipality between 1990 and 2000 in km^2

		Initial State (1990) in km^2					
		Agricultural Land	Built-Up Area	Closed Savannah Vegetation	Opened Savannah Vegetation	Water Bodies	Class Total
Final State (2000) in km^2	Agricultural Land	**69.32**	10.87	5.05	70.12	0.04	155.40
	Built-Up Area	11.05	**79.34**	0.97	93.18	0.04	184.58
	Closed Savannah Vegetation	0.14	0.06	**16.85**	10.72	0.03	27.80
	Opened Savannah Vegetation	81.01	78.24	51.35	**603.21**	0.20	814.00
	Water Bodies	0.25	0.24	1.13	2.79	**0.67**	5.08
	Class Total	161.77	168.75	75.35	780.02	0.98	
	Class Changes	92.45	89.41	58.49	176.81	0.31	
	Image Difference	-6.38	15.83	-47.54	33.99	4.10	

Open Savannah vegetation that remained Open Savannah vegetation was 603.2 km^2 while a total of 176.8 km^2 changed to other LULC types. Built-up area gained 93.2 km^2, Agricultural land gained 70.1 km^2, Closed savannah vegetation gained 10.7 km^2 and Water bodies gained 2.8 km^2 of the total change. The image difference for the Open Savannah vegetation is 34.0 km^2 implying an increase.

Water bodies witnessed an increase in area coverage of 4.1 km^2. The total change in water bodies is 0.3 km^2 of which 0.2 km^2 is to Open Savannah, 0.04 km^2 is to Built-up area, 0.04 km^2 is to Agricultural land and 0.03km^2 is to Closed Savannah vegetation. The area that remained as water bodies is 0.7 km^2.

Table 5 represents the LULC change in Jirapa municipality from 2000 to 2010 while table 6 shows the LULC change between 2010 and 2020. Table 7 shows the Overall LULC change from 1990 to 2020 revealing increases in Agricultural land, Closed Savannah vegetation and Water bodies. Open Savannah vegetation decreased in surface area between 2010 and 2020.

Table 5 Change Matrix of LULC in Jirapa Municipality between 2000 and 2010 in km^2

		Initial State (2000) in km^2					
		Agricultural Land	Built-Up Area	Closed Savannah Vegetation	Opened Savannah Vegetation	Water Bodies	Class Total
Final State (2010) in km^2	Agricultural Land	**86.94**	25.71	0.97	183.15	0.41	297.19
	Built-Up Area	15.38	**98.98**	0.35	87.72	0.30	202.74
	Closed Savannah Vegetation	0.42	0.21	**13.61**	23.33	1.10	38.66
	Opened Savannah Vegetation	51.36	58.82	12.53	**514.72**	2.28	639.71
	Water Bodies	1.29	0.86	0.34	5.05	**0.98**	8.52
	Class Total	155.39	184.58	27.81	813.97	5.07	
	Class Changes	68.45	85.60	14.20	299.25	4.09	
	Image Difference	141.80	18.15	10.86	-174.26	3.45	

Table 6 Change Matrix of LULC in Jirapa Municipality between 2010 and 2020 in km^2

		Initial State (2010) in km^2					
		Agricultural Land	Built-Up Area	Closed Savannah Vegetation	Opened Savannah Vegetation	Water Bodies	Class Total
Final State (2020) in km^2	Agricultural Land	**83.84**	26.77	0.47	101.06	1.68	213.82
	Built-Up Area	83.50	**127.47**	1.45	112.96	0.99	326.38
	Closed Savannah Vegetation	8.75	1.89	**24.34**	48.63	1.28	84.88
	Opened Savannah Vegetation	120.89	46.40	12.19	**375.78**	3.44	558.69
	Water Bodies	0.21	0.22	0.26	1.28	**1.12**	3.10
	Class Total	297.19	202.74	38.71	639.70	8.52	
	Class Changes	213.35	75.27	14.38	263.93	7.39	
	Image Difference	-83.37	123.64	46.17	-81.02	-5.42	

Table 7 Change Matrix of LULC in Jirapa Municipality between 1990 and 2020 in km^2

Final State (2020) in km^2	Initial State (1990) in km^2: Agricultural Land	Built-Up Area	Closed Savannah Vegetation	Opened Savannah Vegetation	Water Bodies	Class Total
Agricultural Land	**43.48**	25.07	6.14	139.11	0.03	213.82
Built-Up Area	36.45	**85.88**	7.12	196.92	0.02	326.38
Closed Savannah Vegetation	6.31	1.57	**27.41**	49.31	0.22	84.83
Opened Savannah Vegetation	75.35	55.82	34.37	**393.07**	0.10	558.70
Water Bodies	0.19	0.41	0.31	1.58	**0.60**	3.10
Class Total	161.77	168.75	75.36	779.99	0.97	
Class Changes	118.29	82.87	47.94	386.92	0.37	
Image Difference	52.05	157.64	9.47	-221.29	2.13	

Land use and Land Cover Prediction for year 2030

The Cellular Automata and Markov Chain (CA-Markov) model were employed to predict future LULC pattern in Jirapa municipality. The CA-Markov model is one of the most extensively used models in LULC change monitoring and prediction. To get reliable results and to authenticate the LULC estimates produced by the CA-Markov Model, 2020 LULC estimates were produced and the extents were compared to the present LULC types produced presented in figure 11. The assessment of the 2020 predicted map and the classified map for year 2020 is presented in table 8.

Table 8 specifies that Agricultural land, Built-up area, Closed savannah vegetation, Open savannah vegetation and water bodies had the best agreement. The predicted map estimates did not deviate much from the values of the actual 2020 LULC map. To better measure the agreement, the kappa coefficient was calculated and used. Kappa (K) coefficient is used because it measures the overall agreement of the matrix with an upper limit of +1.0 (Total agreement) and lower limit of -1 (Less chance of agreement). The K values are above 0.80, representing a high level of accuracy.

Figure 13 shows the simulated LULC map for 2030 and the pie chart in figure 14 is the distribution of the LULC types in the 2030 simulated image. Agricultural land reduced in the predicted map with an area coverage of 146.6 km^2 which represented 12% of the total surface area. Built-up area recorded a significant increase in area coverage of 367.9 km^2, representing 33% of the total landmass. Closed savannah in the 2030 simulated image also increased in area coverage by 109.2 km^2. Open Savannah vegetation is expected to continue to decrease in 2030 as it recorded a coverage of 541.2 km^2 (46%). Water bodies is expected to reduce in coverage as it recorded 2.5 km^2 in the 2030 predicted image with a less than 1% of the total coverage.

DISCUSSION

Land Use and Land Cover Change in Jirapa municipality

Agricultural land in the municipality has not been consistent in its changes as it experienced an increase and decrease in specific years. Agricultural land recorded 164.7 km^2 in 1990 and then reduced to 160.1 km^2 in 2000 followed by a subsequent increase to 300.4 km^2 in 2010 and finally, a decrease to 212.4 km^2 in 2020 (Fig. 15). The change in agricultural land correlates more with changes to Open Savannah vegetation and Built-up area compared to Closed Savannah vegetation and Water (Tables 5 and 6).

Built-up area in Jirapa municipality experienced consistent increase in coverage since 1990 with the highest increase recorded between 2010 and 2020 (Fig. 11). This continuous increase reflects the outward growth of towns and villages in terms of infrastructural development and population. Considering changes in built-up area to other LULC types, Agricultural land and Open savannah vegetation are the major change determinants (Tables 5, 6, 7 and 8).

Table 8 Comparison of 2020 Actual and Predicted LULC Maps

LULC Classes	2020 - Actual LULC		2020 - Predicted LULC	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Agricultural Land	212.41	0.18	212.38	0.18
Built-Up Area	329.78	0.28	327.80	0.28
Closed Savannah Vegetation	88.15	0.07	86.15	0.07
Opened Savannah Vegetation	553.86	0.47	558.52	0.47
Water Bodies	3.19	0.00	2.54	0.00
Total	1187.39	100.00	1187.39	100

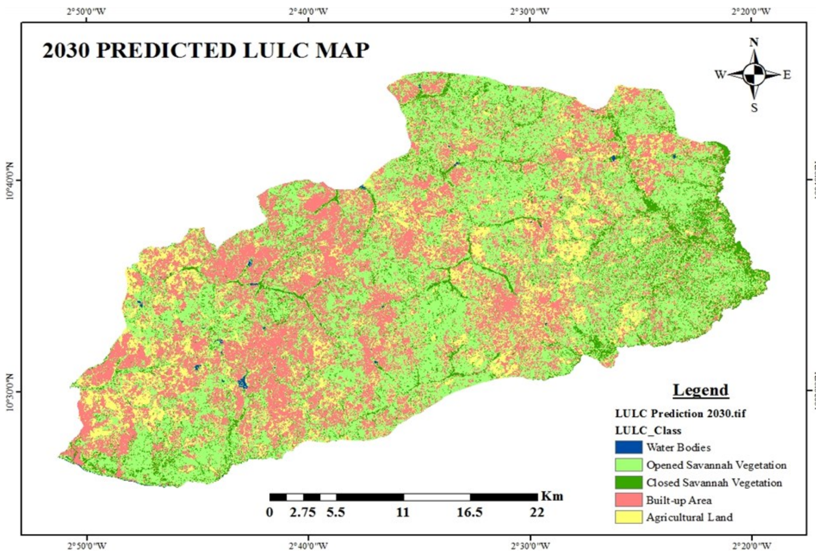

Fig.13 Predicted LULC Map of Jirapa Municipality in 2030

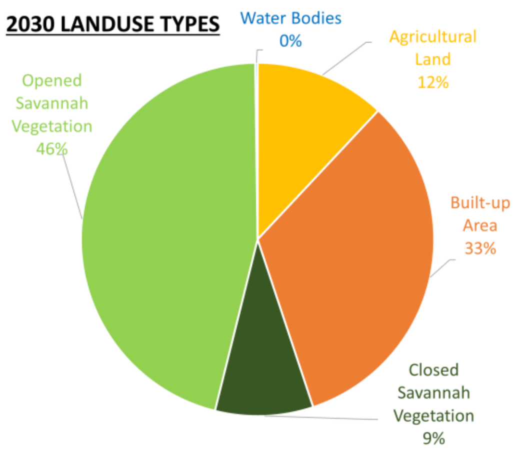

Fig.14 Predicted LULC types in 2030

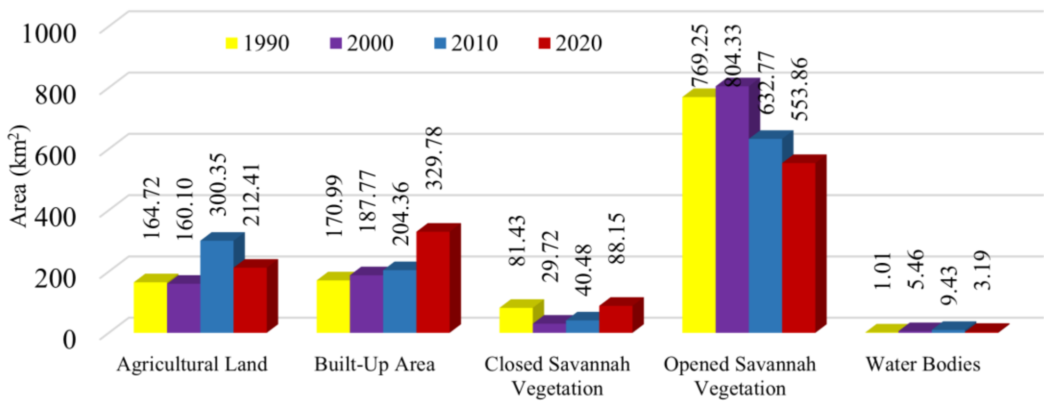

Fig.15 Distribution of LULC Types in Jirapa Municipality

Changes to agricultural LULC type in Jirapa can be attributed to increase in infrastructural development. Farmlands in Jirapa municipality are notably in close proximity to the houses of farmers. Hence, increasing demand for land for building and general infrastructure purposes due to increasing human population means that more agricultural lands have to be converted for residential and infrastructural developments. With the Jirapa municipality being one of the fastest growing districts in the Upper West region in terms of population over the years, increased Built-up areas is to be expected. The population census from 1990 and 2000 (Table 9) corroborates the rapid urbanization in the district as consequent increase in Built-up areas is necessary to accommodate the ever-rising population. This trend influences changes to Agricultural and Open Savannah lands.

Table 9 Population of Jirapa Municipality

Year	Population
1990	41,021
2000	59,604
2010	88,402
2021	91,279

An important factor that influences change to agricultural land is the practice of farmland fallow. As agricultural lands are abundant in the municipality, farmers move to newer lands within the study area, leaving previously cultivated lands bare for years to regain their nutrients. This practice drives changes to Open Savannah and Agricultural lands as evidenced in the results. As fallow lands are eventually re-cultivated, changes to Open Savannah and Agricultural lands are mostly temporal, only remaining the same for only six years or so.

Closed savannah vegtation change is largely affected by deforestation and bushfires in the district. Deforestation in the district has become a challenge as more and more forested areas are cleared for firewood and charcoal. Increasing numbers of urban dwellers leads to increased demand for charcoal and firewood as LPG is not readily available in the district resulting in deforestation. Bush fires are also particularly important during the dry season due to slash-and-burn farming practices and hunting activities.

Water bodies in the district are largely influenced by erosion and infrastructural development as well as agricultural activities. Most of the water bodies in the municipality are dams which are confined to particular areas. The continuous deposit of eroded soil into these water bodies has led to significant reduction in their depth. Rice for example, is largely cultivated along the banks of water bodies and involves processes that lead to increase in depth of the waterbodies due to eroded soil.

Land Use and Land Cover Prediction for the Year 2030

The results show that Built-up areas would have significant influence on other LULC types as they are expected to increase significantly from the 2020 coverage area of 329.8 km^2 to 367.9 km^2 in 2030. This implies that 38.1 km^2 of other LULC types would be converted to Built-up areas with the most affected LULC type being Agricultural land as this would reduce in coverage to 146.6 km^2 in 2030 from 212.4 km^2 in 2020.

While Agricultural lands are expected to reduce in 2030, increasing human population in the district implies that there would be even higher demand for agricultural land. As such, reductions in the Open Savannah vegetation is to be expected which is seen in the decline from 553.9 km^2 in 2030 to 541.2 km^2 in the predicted map (Fig. 13). The increase in coverage of the Closed savannah vegetation to 109.2 km^2 in 2030 from a coverage of 88.2 km^2 is as a result of the maturing of presently young trees around the water bodies. This trend, compounded by more intensive agricultural activities along waterbodies, has a direct influence on the expected coverage of water bodies in 2030 as water bodies are predicted to decrease to 2.5 km^2 from 3.2 km^2 in 2020.

CONCLUSION

The major LULC types identified in Jirapa municipality are Built-up area, Agricultural land, Open Savannah vegetation, Closed Savannah vegetation and Water bodies. While Agricultural land decreased between 1990 and 2000, it increased between 2000 and 2010 and decreased again between 2010 to 2020, reflecting the fallow land practice among farmers within the study area. Built-up areas increased throughout the years under study while Closed Savannah vegetation decreased in 2000 and continued to increase afterwards. Open Savannah vegetation increased in 2000 as a direct consequence of conversion from Closed Savannah vegetation, and thereafter, continued to decrease. Water bodies in the study area increased in 2000 and 2010 and decreased in 2020. These changes are generally as a result of population increase, bushfires, infrastructural development, deforestation, and agricultural activities.

The results of our study are consistent with previous studies such as Iddrisu et al. (2023) whose study predicted a decrease in agricultural lands in Tamale, a town in northern Ghana, as a result of urban expansion. While Koo et al. (2019) used a different methodology, preferring a stakeholder-based modelling approach, to assess land use patterns in northern Ghana, their results are corroborated by this study. This points to the fact that land use changes in northern Ghana are imminent as a result of urbanization.

The predicted LULC map produced for the year 2030 showed that Built-up areas are expected to continue the upward adjustments while Agricultural land reduces. Ongoing urbanization trends in the towns will result in more and more conversion of farmlands to Built-up areas. Open Savannah vegetation is expected to decrease due to increasing demand for more agricultural land while Closed Savannah vegetation increases as young trees near waterbodies mature in 2030. Water bodies are expected to decrease in coverage as agricultural activities such as rice farming, intensify. The identification of protection forest areas in the municipality by the Forestry Commission can help to further increase coverage of Closed Savannah areas, especially if education by the municipal assembly on the use of alternative energy sources such as LPG, is intensified.

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