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RESEARCH PAPER

LAND USE LAND COVER CHANGES IN THE DENSU RIVER BASIN OF GHANA FROM 1991 TO 2020

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ABSTRACT

The Densu basin has a lot of natural resources and serves as a source of livelihood for millions of people in terms of agriculture, tourism, and employment. The basin has undergone a lot of Land Use Land Cover changes which is caused by deforestation, mining and some agricultural practices. This research assessed the rate, extent, and distribution of LULC in the Densu basin of Ghana from 1991 to 2020. Landsat images for 1991, 2002, 2008, 2014, and 2020 were selected for classification with five LULC classes namely; forest, farmland, grass and shrub, bare land and settlement, and waterbodies. The Random Forest Classification algorithm was used for the classification. A total of 250 ground-truthing samples and image interpretation was used in developing training data. Throughout the study period, forest and farmland decreased by 10.27% and 12.19% respectively. Grassland and shrub, bare land and settlement, and waterbodies increased by 4.8%, 17.19%, and 0.47% respectively. The study revealed that many farmlands and forests have been converted into bare land and settlements as a result of urbanization and most of these locations have grassland and shrubs surrounding them for beautification reasons. Activities like salt and sand winning are implicated in the increase in water because they cause craters that eventually fill with water. The overall accuracy ranged from 92 to 96 with the overall kappa ranging from 0.91 to 0.95 indicating a good classification performance. Knowledge of these LULC changes is of great importance to policymakers for the monitoring and protection of natural resources.

Keywords: Accuracy assessment, Classification, Land Use Land Cover, River basin, Urbanization

INTRODUCTION

Globally, most countries are encountering rapid Land Use Land Cover (LULC) changes. These changes have been attributed to the interaction between humans and the environment. Knowledge and monitoring of LULC changes, its severity, causes and effects are essential for ensuring sustainable development planning (Gondwe et al., 2021). Land cover refers to the physical characteristics of land and the biophysical properties of the surface of the earth consisting of soil, water and vegetation whilst land use is how land is used for either social, political, or economic activities (Verburg et al., 2015). Land changes are the modification in land cover or use of land by either the change to a different land use type or strengthening an existing type. It is mostly caused by anthropogenic activities and natural factors (Dadson, 2016; Liping et al., 2018). Anthropogenic activities like farming, mining, overgrazing, residential and industrial expansion, increase in population and increase in demand for natural resources for economic gains cause land use changes and exploitation of natural resources which has a significant environmental impact (Liping et al., 2018). Global climate change, biodiversity loss, loss of soil resources, food scarcity, deforestation and the increase in CO_2 and greenhouse gases are some of the environmental repercussions of LULC changes (Cobbinah *et al*., 2015; Clerici et al., 2019; Hu et al., 2019).

According to United Nations in 2014, more than 50 % of the world's population live in urban areas which invariably result in LULC changes. With the increase in human population and economic development, there is also an increase in the need for natural resources in compensating for the high demand for energy and food (Abass et al., 2018). Knowledge of LULC changes is needed by various stakeholders like urban development planners, environmental protection agencies, and local assemblies for the decision-making processes about natural resource management, environmental monitoring, and urban development planning in order to satisfy the basic needs of mankind and to also achieve sustainable development goals with the aim of also protecting the natural environment for future generations. It also helps to predict the direction of the human induced environmental changes (Kumasi *et al*., 2010; Kamwi *et al*., 2015; Gondwe et al., 2021). Globally research on LULC have been carried out, notably are Northern Germany (Kandziora et al., 2014), Australia (Jamei et al., 2022) and Canada (Chowdhury et al., 2021).

In Africa, LULC is changing rapidly and the rate is attributed to several factors like urbanization which is mostly caused by unplanned expansion and immigration, population growth, climate change, unstable land tenure, deforestation, commercialization and industrialization (Belal and Moghanm, 2011; Hegazy and Kaloop, 2015; Gondwe et al., 2021; Musetsho et al., 2021; Abebe et al., 2022). Regionally, extensive works has been done, notably are Rwanda (Akinyemi, 2017), Togo (Akodewou et al., 2020), South Africa (Dlamini et al., 2021) and Ivory Coast (Kouassi et al., 2021).

In Ghana, there is a high increase in LULC changes due to agricultural activities, mining, deforestation, and urbanization. The alarming nature of this trend has made a lot of researches to research and assess the rate of change in LULC in some parts of the country. Notable amongst them are Volta Basin (Braimoh and Vlek, 2004), New Juaben Municipality (Attua and Fisher, 2011), Lower Volta Basin (Bosompem, 2015), Owabi Reservoir (Antwi-Agyei *et al*., 2019) and Atwima Nwabiagya District (Forkuo *et al*., 2021).

Satellite imagery has played a key role in studying environmental change and managing natural resources (Young and Onoda, 2017).

With the introduction of remote sensing techniques and Geographic Information Systems (GIS), monitoring LULC changes over time has become easy. It is an accurate and cost-effective method (Rawat and Kumar, 2015; Aboelnour and Engel, 2018). The analysis is based on the spatio-temporal remotely sensed data whereby high-resolution images, are processed to assess the rate of change of LULC (Chaudhuri and Mishra, 2016).

The Densu basin is currently one of the fastest growing economic hubs in Ghana which provides a revenue stream to millions of `people in areas such as tourism, agriculture, and employment. Two dams are located on the basin and provide water to about 74% of residents in Accra (Ghana's capital city) and its environs. Sadly, its numerous natural resources are declining by day. The decline is caused by urbanization, population growth and increase in socioeconomic activities. Information with regards to the decline is often lacking which has made it difficult for the various stakeholders to monitor and protect the natural resource and this has necessitated this study. This study was carried out to assess the rate, extent, and distribution of, LULC in Ghana's Densu River Basin from 1991 to 2020 to contribute to literature on LULC changes in the basin, to aid the various stakeholders in sustaining economic activity and urban planning and to forecast future alterations.

MATERIALS AND METHODS

Study area

The Densu basin is situated in Ghana's South-Eastern region within longitudes **0°10**'W -0°37'W and latitudes 5°30'N -6°17'N as shown in Figure 1. The basin covers an area of approximately 2490km^2 and also spans over 11 District and Municipal assemblies in three Regions (Greater Accra, Central, and Eastern). The total length of the Densu river is 116km which flows from the Atewa Range and discharges into the Bay of Guinea (Atlantic Ocean). On the Densu river, two dams namely; Densuano and Weija are located on it and it supplies drinking water to about 74% of Accra (Ghana's capital city) and its environs (WRC, 2022).

The population of the basin is about 600,000 and is distributed to about 200 communities, with a density of 240 people per km^2. There are more people per square kilometer than the national average of 100. About 40% of the population is into agricultural activities like farming, livestock rearing and fishing (Ghana Statistical Service, 2019; Oti et al., 2020).

The vegetation is mostly made up of Coastal Savannah, thicket and grassland in the South and moist semi-deciduous forest in the North (Ghana Statistical Service, 2019).

The majority of the soils are red or reddish brown savanna ochrosols that are friable, porous and well-drained. Generally speaking, they are deficient in nutrients, particularly phosphorus and nitrogen and it is often found in the Northern parts of the basin (Ghana Statistical Service, 2019; Water Resource Commission, 2019). The Densu basin is generally low lying with undulating topography and isolated ridges forming the characteristic landscape features in many places.

The two climatic zones in the basin are the drier equatorial climate toward the coast in the Southeast and the moist semi-equatorial climate in the North with a bi-modal rainfall pattern having different intensities distinguishing both climates. The minor rainy season, on the other hand, lasts from September through November and is distinguished by a less severe rainy season. According to the Ghana Meteorological Agency, the basin has an average annual temperature of 27^{o}C, with maximum temperatures of 32^{o}C in February/March and minimum temperatures of 23^{o}C in December (Adomako et al., 2010; Akurugu et al., 2022;

Ghana Statistical Service, 2019; Water Resource Commission, 2019).

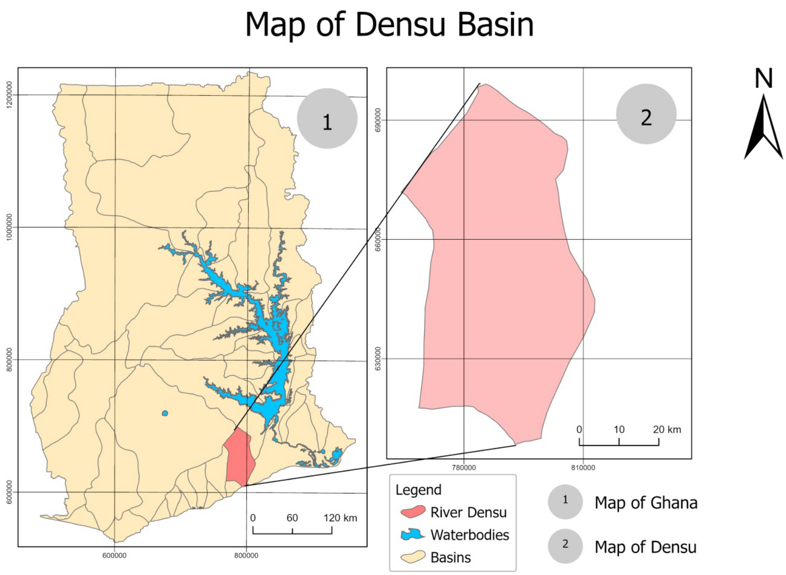

Figure 1 Study area

Data

Landsat Images for 1991, 2002, 2008, 2014, and 2020 were used for the classification and it was acquired from the United States Geological Survey Earth Explorer webpage (http://earthexplorer.usgs.gov). Landsat images were preferred for this study because of its demonstrated capability of their 30m spatial resolution for land cover characterization, easy accessibility, free-cost and long term temporal coverage.

Table 1 Landsat Images: Characteristics and properties

Year of Acquisition	Path/Row	Spatial Resolution	Satellite Sensor
1991	193/056	30m	L5 TM
2002	193/056	30m	L7 ETM+
2008	193/056	30m	L7 ETM+
2014	193/056	30m	L7 ETM+
2020	193/056	30m	L7 ETM+

Image pre-processing

Remote sensing images obtained from satellites are generally geometrically distorted which requires a series of processes to be applied to increase image visualization and interpretation and also make it suitable for analysis. Image processing was carried out to correct for atmospheric and topographic effects on the images as well as other processes like image gap filling and subsetting.

Radiometric errors on the images were corrected by converting the digital number of pixels into spectral radiance values and the radiance into reflectance values. Atmospheric errors were also removed from the images. The Landsat images were projected to Universal Transverse Mercator Zone 30°N.

Gap filling was carried out to correct for the missing data caused by the Scan Line Corrector failure that occurred in 2003 on Landsat 7's ETM+ instrument. Gap lines on the images were removed and missing data filled on all the Landsat images with the exception of Landsat images for 1991 and 2002. Downloaded Landsat images covered larger areas than the study area and in obtaining the area of interest, the satellite images were subsetted using a shapefile of the study area.

Classification

In the identification of the land use classes in the basin, a meeting with elders in the community was organized to know about the classes in the basin and it was also confirmed from ground-truthing and literature. Based on Anderson's Level I Classification Scheme (Anderson et al., 2001), the classes were divided into five (Table 2);

Table 2 Land classes and description

Class	Description
Forest	A large area of mostly trees
Farmland	Fallow, crop, and vegetable lands
Grassland and shrub	Lands with grass and woody plants smaller than trees
Bareland and settlement	Lands with sand or gravel and built-up areas
Waterbodies	Rivers, small ponds, streams, and reservoirs

Source: Modified Anderson's Classification Scheme (Anderson, 2007)

The clipped images were subjected to supervised classification with the ground-truthing data serving as the training data for the various classes. A total of 250 ground-truthing samples (with 50 samples for every class) were collected with a handheld Global Positioning System (GPS) using the WGS 84 and UTM Zone 30°N projection. 250 points from the ground-truthing samples were used for the classification (70% for training and 30% for validation). The ground samples in combination with a visual interpretation of Landsat images aided in the development of truth points. For each LULC class, polygons of homogenous pixels were created around each truth point and saved as a vector layer of training data. Pixel values from the training data were compared to every pixel in the image using a Random Forest classification algorithm which classified the entire image based on close resemblance to the pixels in the training data. The Random Forest classification algorithm was used because it has excellent accuracy compared to the other classification algorithms, it can incorporate different data sources, and can also work with large data sets (Mellor et al., 2013; Ming et al., 2016).

Accuracy assessment

The correlation between satellite image classification and ground reference samples gathered was assessed for accuracy to evaluate the total agreement between processed classification and ground-truthing data. Overall accuracy and the kappa coefficient were used to assess accuracy. Overall accuracy indicates the quality of the image classification whilst the kappa coefficient measures the agreement between classification and true values; a value of 1 shows there is perfect agreement whilst a value of 0 represents no agreement (Rwanga and Ndambuki, 2017).

Change detection

Change detection helps to determine the area of coverage of each class within a period by quantifying the differences between two images of the same scene obtained at the start and the end of the desired study period using their pixel counts. The magnitude of change was assessed by comparing the LULC classification maps to the change maps.

RESULTS

Land Use Land Cover maps

The Densu River Basin was classified into five LULC types, namely; forest (an area covered by multiple tree species in various canopies and forest land), farmland (an area designated for farming), grassland and shrub (perennial woody plants and grasses), bare land and settlement (impervious surfaces such as residential, commercial, industrial, transportation, and other concrete surfaces), and waterbodies (river Densu and other water bodies within the catchment).

Figure 2 shows the spatial distribution of each class whilst Figure 3 shows the percentage coverage of each class for the respective years. Table 3 shows the area and percentage coverage of each class for the respective years.

In 1991, the forest covered an acreage of 405705.30 (58.60%), farmland; grassland and shrubs covered an acreage of 210260.58 (30.37%) and 9277.22 (1.34%) respectively, whilst bare land and settlement, and waterbodies covered an acreage of 9277.22 (1.34%) and 22916.12 (3.31%) respectively as shown in Figure 3 and Table 3.

Similarly, in 2002 forest covered the majority of the land cover with acreage of 444337.31 (64.18%). Farmland; grassland and shrubs covered an acreage of 128565.66 (18.57%) and 35239.59 (5.09%) respectively, whilst bare land and settlement, and waterbodies covered an acreage of 64178.98 (9.27%) and 20008.33 (2.89%) respectively as shown in Figure 3 and Table 3.

In 2008, forest covered the majority of the land cover with an acreage of 331487.54 (47.88%), farmland, and grassland and shrub covered an acreage of 158474.31 (22.89%) and 42785.99 (6.18%) respectively, whilst bare land and settlement, and waterbodies covered an acreage of 136388.98 (19.7%) and 23193.05 (3.35%) respectively as shown in Figure 3 and Table 3.

Similarly, in 2014 forest covered the majority of the land cover with an acreage of 314871.62 (45.48%). Farmland; grassland, and shrub covered an acreage of 166436.09 (24.04%) and 42647.52 (6.16%) respectively, whilst bare land and settlement, and waterbodies covered an acreage of 147397.03 (21.29%) and 20977.59 (3.03%) respectively as shown in Figure 3 and Table 3.

In 2020, forest covered an acreage of 334603.02 (48.33%), farmland, and grassland and shrub covered an acreage of 125865.57 (18.18%) and 42509.05 (6.14%) respectively, whilst bare land and settlement, and waterbodies covered an acreage of 163172.15 (23.57%) and 26170.07 (3.78%) respectively as shown in Figure 3 and Table 3.

The classified area covers a total area of 692665.03 acres.

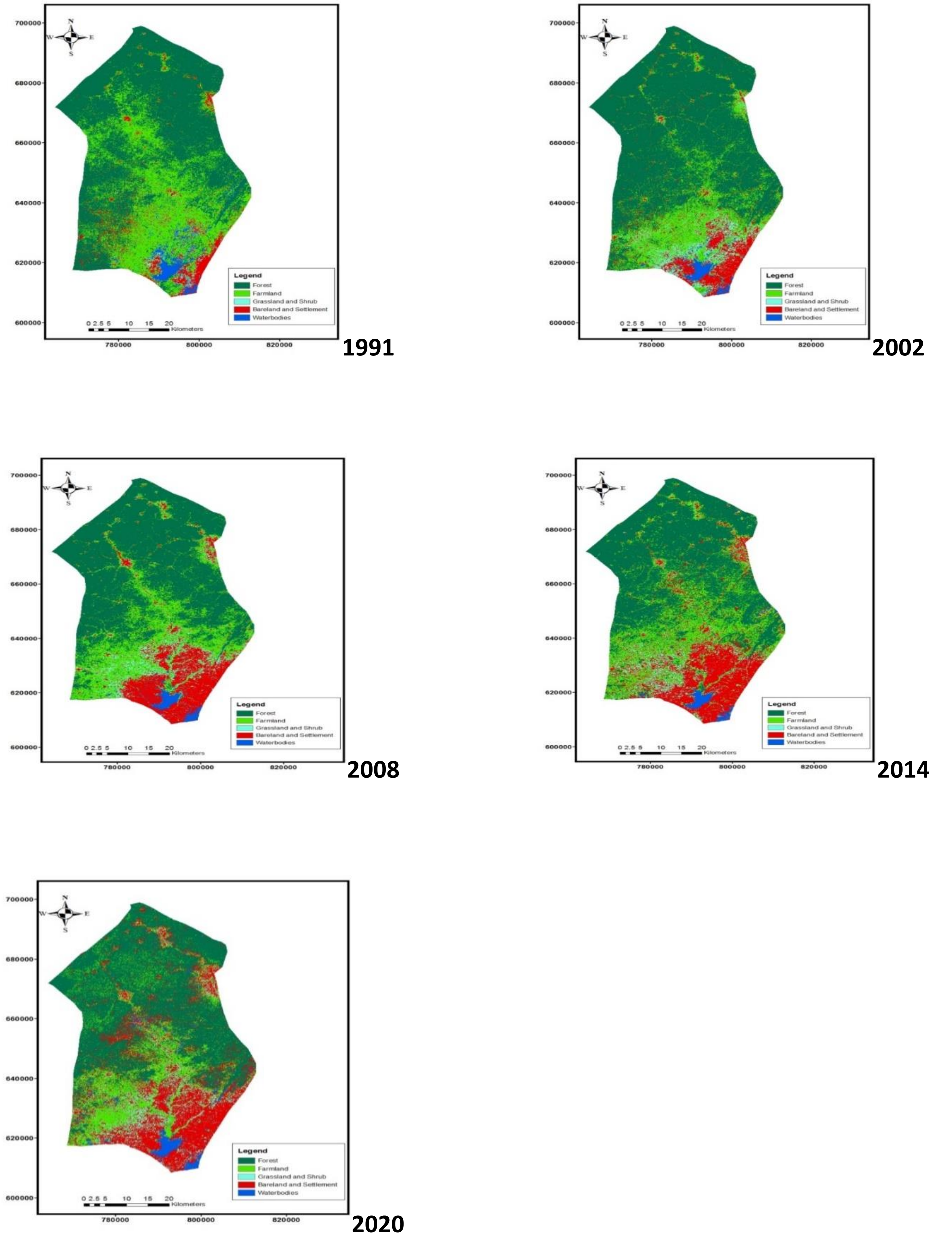

Figure 2 LULC maps for 1991, 2002, 2008, 2014 and 2020

Table 3 Area covered by LULC classes

Year	Area	Forest	Farmland	Grassland and Shrub	Bareland and settlement	Waterbodies	Total
1991	**Acres**	405705.30	210260.58	9277.22	44170.65	22916.12	692329.87
	%	**58.60**	**30.37**	**1.34**	**6.38**	**3.31**	**100**
2002	**Acres**	444337.31	128565.66	35239.59	64178.98	20008.33	692329.87
	%	**64.18**	**18.57**	**5.09**	**9.27**	**2.89**	**100**
2008	**Acres**	331487.54	158474.31	42785.99	136388.98	23193.05	692329.87
	%	**47.88**	**22.89**	**6.18**	**19.7**	**3.35**	**100**
2014	**Acres**	314871.62	166436.09	42647.52	147397.03	20977.59	692329.87
	%	**45.48**	**24.04**	**6.16**	**21.29**	**3.03**	**100**
2020	**Acres**	334603.02	125865.57	42509.05	163182.15	26170.07	692329.87
	%	**48.33**	**18.18**	**6.14**	**23.57**	**3.78**	**100**

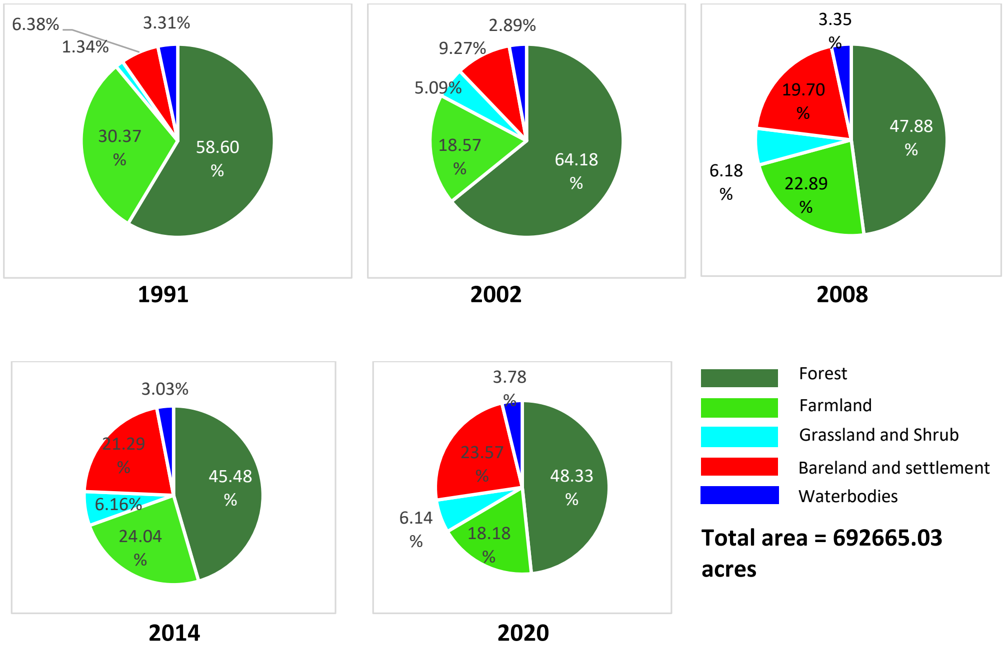

Figure 3 Area covered by LULC classes

From the above, it can be established that the forest and farmlands are decreasing while water bodies are marginally increasing. Grassland and shrubs are also increasing steadily while bare land and settlements increases uniformly.

Rate of change of area for the various classes

Table 4 shows the rate of change of area coverage for each class for the respective years with Figure 4 also showing a graphical representation.

Between 1991 to 2002, forest, grassland and shrub, and bare land and settlement, increased by 5.58%, 3.75% and, 2.89% respectively with farmland and waterbodies decreasing at a rate of 11.8% and 0.42% respectively as shown in Table 4 and Figure 4. From 2002 to 2008, farmland, grassland and shrub, bare land and settlement, and waterbodies increased by 4.32%, 1.09%, 10.43%, and 0.46% respectively with forest declining at a rate of 16.3% as shown in Table 4 and Figure 4. From 2008 to 2014, farmland, bare land, and settlement, increased by 1.15% and 1.59% respectively with forest, grassland and shrub, and waterbodies decreasing at a rate of 2.4%, 0.02%, and 0.32% respectively as shown in Table 4 and Figure 4. Between 2014 to 2020, forest, bare land, settlement, and waterbodies increased by 2.45%, 2.28%, and 0.75% respectively with farmland, and grassland and shrub decreasing at a rate of 5.86% and 0.02% respectively as shown in Table 4 and Figure 4.

Throughout the study period (from 1991 to 2020), forest and farmland decreased by 71102.28 acres (10.27%) and 84395.01 acres (12.19%) respectively, whilst grassland and shrub, bare land settlement, and waterbodies increased by 33231.83 acres (4.8%), 119011.51 acres (17.19%) and 3253.95 acres (0.47%) respectively as shown in Table 4 and Figure 4.

Table 4 Rate of change of area for the various LULC classes

Year	Area	Forest	Farmland	Grassland and Shrub	Bareland and settlement	Waterbodies
1991 - 2002	**Acres**	38632.00	-81694.92	25962.37	20008.33	-2907.79
	%	**5.58**	**-11.8**	**3.75**	**2.89**	**-0.42**
2002 - 2008	**Acres**	-112849.77	29908.65	7546.40	72210.01	3184.72
	%	**-16.3**	**4.32**	**1.09**	**10.43**	**0.46**
2008 - 2014	**Acres**	-16615.92	7961.79	-138.65	11008.05	-2215.46
	%	**-2.4**	**1.15**	**-0.02**	**1.59**	**-0.32**
2014 - 2020	**Acres**	19731.40	-40570.53	-138.47	15785.12	5192.47
	%	**2.45**	**-5.86**	**-0.02**	**2.28**	**0.75**
1991 - 2020	**Acres**	-71102.28	-84395.01	33231.83	119011.51	3253.95
	%	**-10.27**	**-12.19**	**4.8**	**17.19**	**0.47**

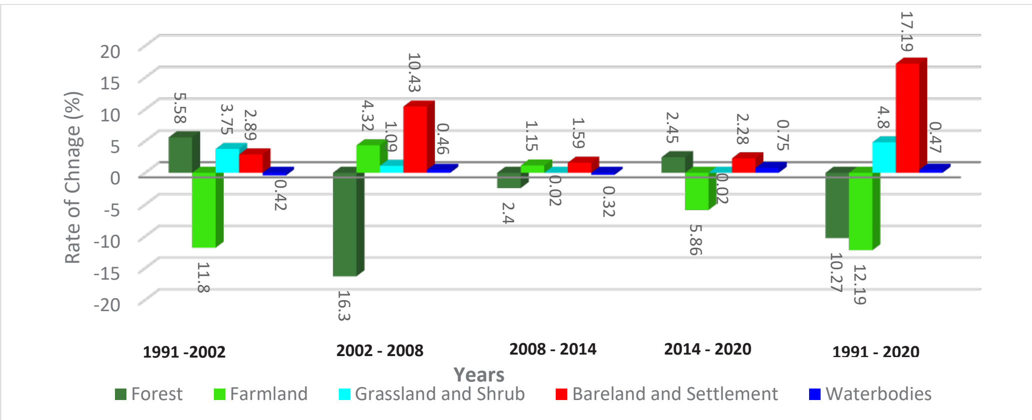

Figure 4 Rate of change of area for the various LULC classes

From Table 4 and Figure 4, it can be established that settlement and bare land had the highest positive rate of change in the area between 2002 and 2008. Likewise, forest had the highest negative rate of change between 2002 and 2008. Also, farmland had the highest negative rate of change from 1991 to 2002. Grassland and shrubs had the highest positive rate of change from 1991-2002. Water bodies had a steadily positive rate of change throughout the study period.

Accuracy assessment

The classification accuracy was assessed using the overall accuracy and kappa statistics. The overall accuracy ranged from 92 to 96 with 1991, 2002, 2008, 2014, and 2020 having an overall accuracy of 92, 96, 95, 94, and 93 respectively. Kappa ranged from 0.91 to 0.95 with 1991, 2002, 2008, 2014, and 2020 having a Kappa of 0.91, 0.95, 0.94, 0.93, and 0.91 respectively as shown in Table 5.

Table 5 Overall accuracy and Kappa for the various years

Year	Overall accuracy	Kappa
1991	92	0.91
2002	96	0.95
2008	95	0.94
2014	94	0.93
2020	93	0.91

DISCUSSION

This study analyzed five LULC classes namely; forest, farmland, grassland and shrub, bareland and settlement, and waterbodies in the Densu river basin from 1991 to 2020.

Throughout the study period, forest and farmland which had been the dominant class decreased by 10.27% and 12.19% respectively. From previous research in the basin, the decrease in farmland and forest areas was attributed to the increase in demand for land and land degradation activities such as deforestation, slash-and-burn farming, livestock grazing (Ayivor & Gordon, 2012; Adjei et al., 2019). The decrease can also be attributed to the decrease in rainfall pattern and increase in temperature (Higginbottom and Symeonakis et al., 2014; Chen et al., 2018). From Figure 2, most forests and farmlands were converted to bare land and settlements and according to Boafo (2013), Ghana lost almost a quarter of its entire forest from 1990 to 2005. According to Singh *et al*., (2010), Antwi *et al*., (2014), and Addo-Fordjour and Ankomah (2017), urbanization and population growth is the key driver of LULC change in Ghana and most developing countries. A surge in urbanization has resulted from population growth which has caused the depletion of forest areas and farmlands for the expansion of social amenities and infrastructure (residential, commercial, and industrial) (Tahir *et al*., 2013; Acheampong and Anokye, 2013; Appiah *et al*., 2014; Appiah *et al*., 2015; Addae and Oppelt, 2019; Antwi-Agyei et al., 2019). Lack of employment opportunities and social amenities in rural areas is a leading cause of rural-urban migration in most developing countries. In Namibia and Kenya, increase in population and agricultural expansion have been identified as the key drivers of LULC changes (Antwi-Agyei et al., 2019). Between 2007 and 2012, prices of land in Ghana increased by over 200% (Yalley and Ofori-Darko, 2012) and this has led many traditional leaders who are custodians of the land to sell forest areas and farmlands to potential land buyers for residential and commercial purposes (Forkuo and Adubofour, 2012; Addae and Oppelt, 2019) and the citing for these purposes are sometimes at rural areas near the outskirts of urban areas and has led to massive loss of farmlands (Acheampong et al., 2018). The decrease in farming activities causes poverty and threatens livelihood by the shortage of food and reducing sources of employment for the native farmers within the basin since 40% of the locals are into agriculture. The depletion of the forest and farmlands significantly affects the water bodies and climate since these land cover types tend to protect the water bodies against evapotranspiration and also store the carbon stocks in the environment (Acheampong et al., 2018; Adjei et al., 2019).

During the study period, bareland and settlement increased by 17.19% and which is dominant in the Southern section as shown in Figure 2 and according to Asare-Nuamah and Botchway (2019), the Southern section of the basin has activities like salt and sand winning, overgrazing, settlement for residential, commercial and industrial purposes been dominant. From the study, consistent increase in bare land and settlement is attributed to the increasing urbanization in areas like Koforidua, Kasoa, part of Accra, Adeiso, Nsawam, and Suhum (Yorke & Margai, 2007, Ayivor & Gordon, 2012; Adjei et al., 2019; GSS, 2021;) According to Kouassi et al., 2021, from 1985 to 2015, urban areas have expanded by 80% and the contributing factor is population growth and the incapability of available lands in sustaining the growth. The increase in settlement and bare land around the water bodies has a high potential of affecting the water quality within the basin (Adjei et al., 2019). This increase also causes an increase in temperature and urban heat island (causing the greenhouse effect) as well as reduces the amount of rainfall within the basin and the surrounding areas (IPCC, 2007; Olofin & Oluwadare, 2022).

Grassland and shrub showed an increase of 4.8% throughout the study period, and this is attributed to the inability of some land buyers to fully develop lands after clearing the forest or farm crops thereby leaving it bare and also grass and shrubs grown for beautification purposes after developing lands. Waterbodies increased by 0.47% during the study period and this is attributed to the increase in salt and sand winning activities which normally leaves crates that eventually become filled with water when it rains (Asare-Nuamah and Botchway, 2019).

This study is similar to works done by Kafi et al., (2014), they did a study on the analysis of land use land cover change detection using remotely sensed data, a case study of Bauchi city from 2003 to 2013. In the study, four classes were similar to the ones in this study namely; built-up, wetland/ bodies, farmland and shrub/grass. For the duration of the study, farmland decreased by 92.8 km^2 whilst shrub/ grass, built-up and wetland/bodies increased by 62.7 km^2, 36.4 km^2 and 4.6 km^2 respectively. Basommi et al., 2015 also explored land use land cover change in the mining area of Wa East District of Ghana using satellite imagery from 1991 to 2014. Five classes namely; open savannah, closed savannah, bare gound, settlement and water were classified. From the study, open savannah and closed savannah decreased by 14.25% and 5.13% respectively. Bare ground, settlement and water increased by 10.14%, 9.21% and 0.04% respectively. Acheampong et al., 2018 did a study on land use land cover change in Ghana's oil city from 1986 to 2016 whereby four classes namely; forest area, agricultural land, urban area and water were classified. Forest and agricultural land decreased by 29.80 km^2 and 15.76 km^2 respectively whilst urban area and water increased by 44.88 km^2 and 0.84 km^2 respectively. Roy and Inamdar, 2019 also did a study on the multi-temporal land use land cover change analysis of Shivna River Basin in Western India from 1972 to 2014. From the study, forest and agricultural land decreased by 308.74 km^2 and 136.33 km^2 respectively whilst built-up and water increased by 9.34 km^2 and 13.79 km^2 respectively. This study is also consistent with the findings of Adjei et al., (2019) which also revealed the same trend of land use land cover change in the Densu river basin from 1986 to 2018.

According to the Anderson classification scheme, maps with a minimum accuracy of 85% and kappa higher than 0.7 have a higher image classification quality (Anderson *et al*., 1976; Wondrade et al., 2014; Liping et al., 2018). The overall accuracy ranged from 92 to 96 with kappa ranging from 0.91 to 0.95. The results obtained are similar to studies by Tilahun and Islam, 2015; Abdelkareem *et al*., 2018; Abebe et al., 2022. The overall accuracy and kappa statistics was within the acceptable range for a good classification performance.

CONCLUSION AND RECOMMENDATIONS

The research assessed LULC changes in Ghana's Densu River basin using GIS and remote sensing techniques. The study area was categorized into five classes namely; forest, farmland, grassland and shrub, bareland and settlement, and waterbodies. Forest and farmland decreased by 10.27% and 12.19% respectively and this decrease was attributed to the increase in population which caused a surge in urbanization and also an increase in the prices of land. Grassland and shrub, bareland and settlement and water bodies increased by 4.8%, 17.19%, and 0.47% respectively. Urbanization has caused many forest and farmlands to be converted to bareland and settlement and most of such places have grassland and shrub around them for beautification purposes. The increase in water is attributed to activities like salt winning and sand winning which creates a crater and later becomes filled with water. For accuracy assessment, there was a good performance of the classified images due to the overall accuracy within the range of 92 to 96 and overall kappa within the range of 0.91 to 0.95. This study will be useful to the various stakeholders in protecting, planning, and monitoring the various natural resources in the basin. For future works, a prediction model for LULC should be developed to forecast future LULC changes.

DECLARATION OF COMPETING INTEREST

The authors declare no conflict of interest and that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DISCLOSURE STATEMENT

The author declares no conflict of interest.

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