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Land Cover Changes in Ghana over the Past 24 Years

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Abstract: Changes in land cover (LC) can lead to environmental challenges, but few studies have investigated LC changes at a country wide scale in Ghana. Tracking LC changes at such a scale overtime is relevant for devising solutions to emerging issues. This study examined LC changes in Ghana for the past almost two and half decades covering 1995–2019 to highlight significant changes and opportunities for sustainable development. The study used land cover data for six selected years (1995, 2000, 2005, 2010, 2015, and 2019) obtained from the European Space Agency. The data was analyzed using R, ArcGIS Pro and Microsoft Excel 365 ProPlus. The original data was reclassified into eight LC categories, namely: agriculture, bare area, built-up, forest, grassland, other vegetation, waterbody, and wetland. On average, the results revealed 0.7%, 131.7%, 23.3%, 46.9%, and 11.2% increases for agriculture, built-up, forest, waterbody, and wetland, respectively, across the nation. However, losses were observed for bare area (92.8%), grassland (51.1%), and other vegetation (41%) LCs overall. Notably, agricultural land use increased up to 2015 and decreased subsequently but this did not affect production of the major staple foods. These findings reveal the importance of LC monitoring and the need for strategic efforts to address the causes of undesirable change.

Keywords: Ghana; land cover; sustainable development; urbanization; natural resources; population

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1. Introduction

Changes in land cover and land use (LULC) is currently an important subject of discussion worldwide as it is regarded as one of the leading factors causing global change [1]. Though most people in the world now live in urban areas [2], the majority of the urban growth is projected to occur in developing regions of the world [3] with Africa being at the forefront of this growth [4,5]. In fact, it is forecasted that about 56% of people in Africa will live in urban areas by 2050.

Ghana, similar to most developing countries, is growing rapidly in population, as projected. It has grown in population from about 5 million during independence in 1957 to 31 million in 2020 [5] representing an addition of about 26 million people over its 64 years of existence as a sovereign nation. Significant changes in LULC have accompanied this population growth including the expansion of cities, especially Accra, Kumasi, Tamale, and Sekondi-Takoradi [1,4–7]. Since 2010, more than 50% of Ghanaians have been living in urban areas and this population is expected to grow to about 70% by 2050 [8].

On a broad scale, the drivers of LULC are grouped into two: those originating from human activities and those from natural forces. A significant human activity is the growth and size of the human population, whose growth can be moderated by institutional factors, national, and regional policies as well as globalization activities [9]. This implies that LULC transformation is often complex, comprising interactions between several factors including economic, political, demographic, and environmental, but political and economic factors are by far considered to be the most important [10]. Reasons identified in the literature as influencers of LULC changes in Ghana mirror the contention of McNeill et al. [10]. They are primarily spinoffs of economic and/or political drivers including economic growth, commercialization, industrialization, rural-urban migration, and globalization. For example, the growth of the Greater Accra Metropolitan Area comprising Accra, the National Capital, and the Port City of Tema owes its expansion to government microeconomic policies and modernization efforts including the establishment of Tema, industrial estates and the accommodation of several corporate offices of major financial and industrial companies [4]. Similarly, the expansion of the Sekondi-Takoradi metropolitan area is attributed firstly to the expansion of the Takoradi harbor under Ghana's Economic Recovery Program, which was executed under the Structural Adjustment Programs carried out by the World Bank and the International Monetary Fund [1]. Secondly, the discovery of offshore oil deposits in commercial quantities near the area in 2007 resulted in a second wave of urban expansion [11]. The expansion of Kumasi is attributed largely to rural-urban migration owing to the growth in industrial and commercial activities within the city and its environs [9]. Similarly, growth in Tamale is credited to migration from poor rural areas in the northern parts of Ghana [12].

LULC changes have negative impacts [2,13,14] including deforestation, loss of biodiversity, mitigated ability of land in urban areas to provide ecosystem services and loss of agricultural land. Hence, it is imperative to continuously monitor LULC changes to identify resulting challenges and needs for action. Since geospatial technologies are not well developed in most developing countries including Ghana, Remote Sensing and Geographic Information System techniques are essential tools for studying LULC at various spatiotemporal scales [15–17]. Several authors have applied these methods to study LULC changes in Ghana across various spatial and temporal scales spanning regional, district, city/municipal and river basin scales and covering between few and several years. Published regional LULC studies comprise land use appraisal and modeling future change dynamics [18], analysis of LULC spatial patterns and identification of spatial determinants [19–21], transformations in forests both inside and outside protected areas [22], determining classes of LULC around the coastal cities [23], determining relationships between LULC and demographic changes [24]. The District level studies span issues including evaluating the impacts of surface mining on LULC [15,25] and determining the drivers of LULC changes in peri-urban areas [26–28]. LULC studies conducted at the city/municipal level in Ghana mostly capture LULC change patterns, the drivers and impacts and implications in different locations across the country including Accra and Kumasi metropolitan areas [4,5], Sekondi-Takoradi metro area [1,29], New Juaben [30] and Kintampo North Municipality [31]. Some of the city/municipal level studies compared the patterns of urban development between cities in the northern and southern parts of Ghana [32]. The river basin scale studies covering the Lake Bosomtwe Basin, White and Black Volta River Basins and the Pra River Basin had different foci including assessment of land cover transitions and dynamics [33]; evaluating the impacts of climate change and LULC change patterns and impacts on hydrology [34,35] and an examination of land cover changes emanating from widespread gold mining, urbanization, and agriculture [36]. Other authors [37] have reviewed studies on changes in land use on sedimentation of water bodies but few studies have evaluated the LULC changes across Ghana over a significant period. More so, Ghana's economy is largely dependent on agricultural activities and the extraction of mineral resources, which pose environmental challenges and expose the necessity for routine monitoring of LULC changes across the country to identify emerging challenges and need for action. We expect changes in land cover (LC) over time, because of the population increase and its associated pressures on resource use and economic activities. As a result, the objective of this study is to examine LC changes in Ghana for the past almost two and half decades spanning 1995–2019 to highlight the significant changes and opportunities for sustainable development.

2. Materials and Methods

2.1. Study Area

The study area is the country of Ghana (Figure 1). Ghana is located on the west coast of Africa and shares its eastern, western, and northern borders with Togo, Côte d'Ivoire, and Burkina Faso, respectively. Its southern border is the Gulf of Guinea and the Atlantic Ocean. The United Nations Population Division [5] estimated Ghana's 2020 population to be around 31,073,000. The country, whose geographical coordinates are 7.9465° N, 1.0232° W, occupies an area of 238,533 km^2 [9] and has a tropical climate. The northern part of Ghana has a Sudanian type climate characterized by a short rainy season (unimodal) while the southern part experiences higher rainfall regimes (bimodal) and is forested especially in the southwest [9]. The climate conditions here have characteristics of the Guinean and Guineo-Congolian type climate. Agriculture is an important economic sector in Ghana as it employs about half of the population. Ghana is also endowed with natural resources including timber, gold, diamonds, bauxite, manganese, and oil. Since Ghana's economic development is directly dependent on the extraction of natural resources, the country faces troubling environmental challenges [9].

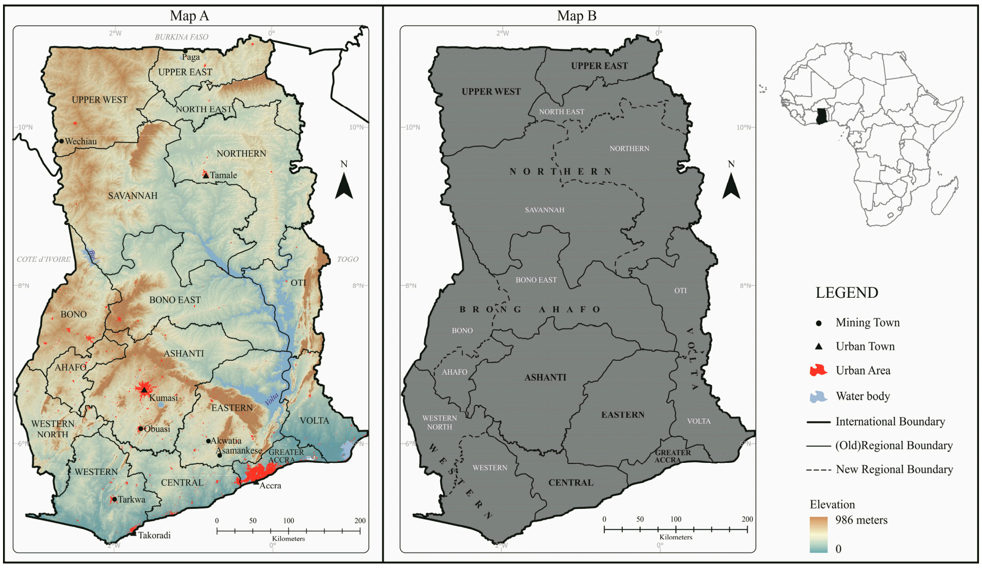

Figure 1. The current 16 Administrative Regions in Ghana (Map **A**) and the previous 10 Regions, from which additional six Regions were carved from (Map **B**). Ahafo, Bono and Bono East Regions were created from the former Brong Ahafo Region. Similarly, the former Northern Region was split into Northern, North East and Savannah Regions while the former Western Region was separated into Western and Western North Regions and the former Volta Region was divided into Volta and Oti Regions.

2.2. Data Used

Landcover data for six selected years obtained from the European Space Agency was analyzed for this study. The years include 1995, 2000, 2005, 2010, 2015, and 2019. All the years selected are at five-year intervals except 2019, because 2020 data was not available at the time of the data acquisition. Awotwi et al. [36] also used satellite imagery data ranging from three to five years to investigate LULC changes in the Pra River Basin in Ghana. They argued that while 10-year timeframes are typical, there is a likelihood of considerable change occurring within that period because of human activity which is by far the most impactful driver of LULC according to a CILSS [9] report.

In this study, LC data for 1995 is considered as a baseline. The global landcover data was downloaded from the European Space Agency (ESA) Climate Change Initiative (CCI) Copernicus Climate Change Service (C3S) Climate Data Store (CDS) in NetCDF formats (Table 1). The LC data acquired has a spatial resolution of 300 m with a geographic coordinate system based on the World Geodetic System 84 (WGS84) reference ellipsoid.

Each of the raster's pixel value corresponds to the label of a LC class based on the UN Land Cover Classification System (LCCS), developed by the United Nations Food and Agriculture Organization [38]. The following satellite sensors captured the land cover datasets; Advanced Very High-Resolution Radiometer (AVHRR) for 1995, Satellite Pour l'Observation de la Terre—Vegetation (SPOT-VGT) for 2000, Medium Resolution Imaging Spectrometer (MERIS) Full Resolution (FR) and Reduced Resolution (RR) for 2005 and 2010, and Project for On-Board Autonomy, with the V standing for Vegetation (PROBA-V) for 2015 and 2019.

Table 1. Original and reclassified land cover categories used †.

Original Category		Reclassified Category	
Landcover	**Code**	**Landcover**	**Code**
Urban areas	190	Built-up	190
Mosaic herbaceous cover Grassland	110 130	Grassland	110
Shrubland Sparse vegetation Shrub or herbaceous cover	120, 122 150, 153 180	Other Vegetation	120
Bare areas	200, 201, 202	Bare Area	200
Rainfed cropland Irrigated cropland Mosaic cropland (>50% vegetation) Mosaic natural vegetation	10, 11 20 30 40	Agriculture	10
Tree cover (broadleaved evergreen) Tree cover (broadleaved deciduous) Mosaic tree and shrub	50 60, 62 100	Forest	50
Tree cover (flooded, fresh, or brackish water) Tree cover (saline water)	160 170	Wetland	170
Water bodies	210	Water body	210

† The original land cover data set was acquired from the European Space Agency (ESA) and the reclassification approach used was influenced by ESA [38].

Figure 2 illustrates the logical model underlying this processing chain. The processing combined the GlobCover unsupervised classification chain from Bicheron et al. [39] and a machine learning algorithm on a multiple-year strategy from Bontemps et al. [40]. Detailed information on the processing is provided by the ESA [38]. Based on the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (CEOS-WGCV), the overall accuracy values weighted by the area proportions of the LC classes were 71.7% [38]. The geospatial data used in the study, which are shapefiles for towns and Ghana's regional administrative boundaries were obtained from Maphouse Ghana Limited in Accra, Ghana. Crop production data for 2011 and 2019 were obtained from the Ministry of Food and Agriculture [41,42].

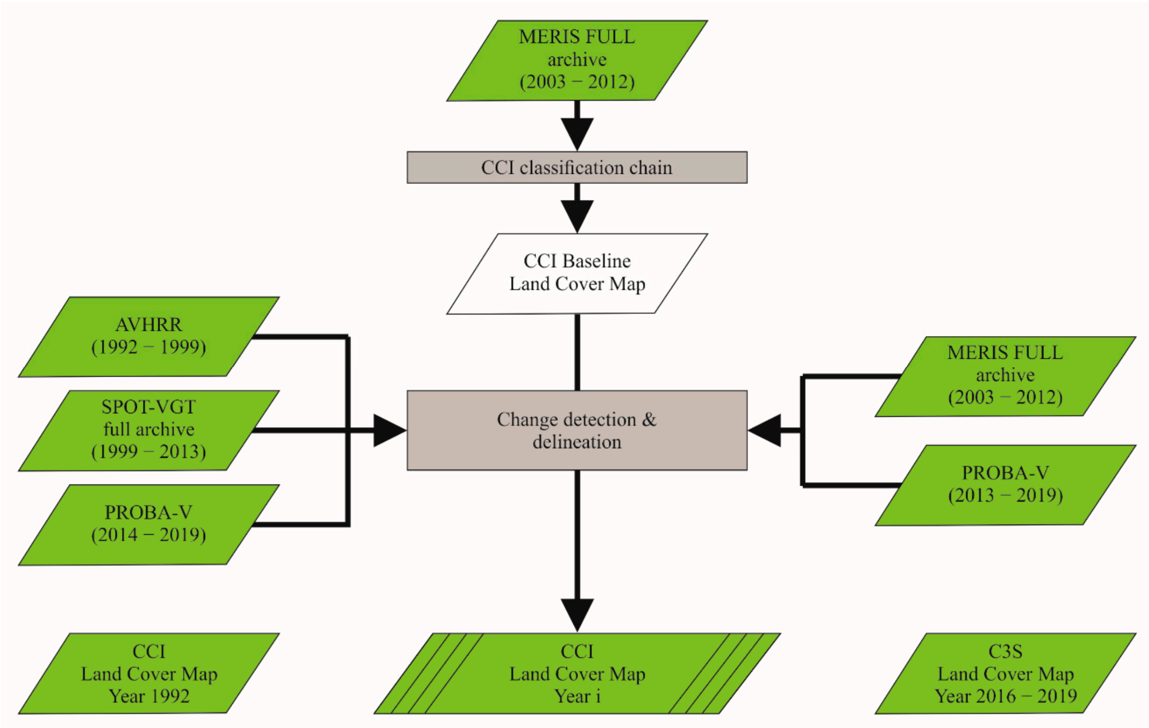

Figure 2. Schematic representation of the land cover classification chain, created by authors based on [38].

Though the data set used in this study may have some limitations, it is important to note the following. First, the overall accuracy of the dataset must be balanced by the fact that the quality of the landcover maps vary according to the thematic class. Land cover classes such as rainfed and irrigated croplands, broadleaved evergreen forest, urban areas, bare areas, and water bodies are quite accurately mapped. On the other hand, classes such as lichens and mosses, sparse vegetation and flooded forest with fresh water can be affected by errors. Second, to allow the detection of change from an old class to a new class, the method developed needs to observe the new class for at least two consecutive years [38]. Thus, abrupt changes are better captured than gradual ones. Abrupt changes are sudden LC transitions from one Intergovernmental Panel on Climate Change IPCC class to another, which most often last more than two years (e.g., a forest loss to an agriculture class). However, since five-year intervals were used, the change over time is more gradual than abrupt. Finally, though a 300 m dataset may seem to be coarse, the spatio-temporal scale of mapping employed with a complete and consistent Copernicus dataset from the ESA was more beneficial than problematic.

2.3. Data Analysis

Figure 3 outlines the data analysis approach used for this study. The data collected was processed and analyzed using three software packages: R version 4.0.2 [43] (R Core Team, 2013), ArcGIS Pro 2.7 (Environmental Systems Research Institute, Redlands, CA, USA) [44], and Excel 365 ProPlus (Microsoft Corporation, Redmond, WA, USA) [45]. R was used to subset the Ghana landcover data from the global datasets. The NetCDF landcover files were converted to raster data and masked to the size of Ghana with the regional boundary shapefiles (through the 'raster', 'ncdf4', and the 'rgdal' packages) because it is faster than doing so in ArcGIS Pro. The rest of the geospatial processing, analyses, and visualization were done using ArcGIS Pro. To activate the attribute tables for the masked raster data, the data was reclassified using the reclassify tool from their pixel values to the coded ones (Table 1). This reclassification was informed by ESA [38]. The areas (km^2) for the respective land covers were calculated using the Zonal Geometry as a table tool. Changes between the various land covers over time was achieved by intersecting for example, the 1995 and the 2019 land covers. Next, all the LC changes were mapped with ArcGIS Pro. The zonal geometry attributes were exported as DBF tables and further analyzed in Excel to obtain statistical values and figures.

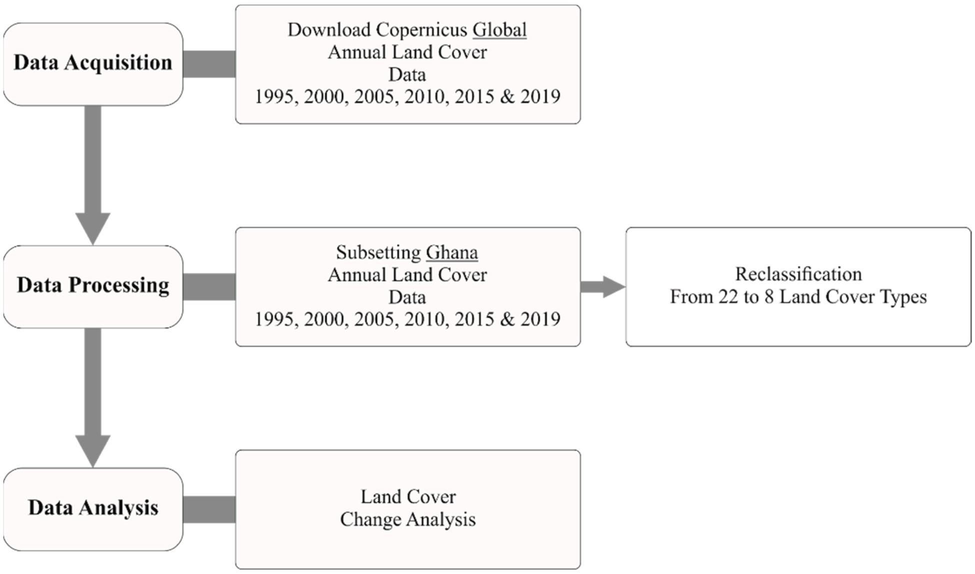

Figure 3. The land cover data analysis flow chart.

3. Results

The results of the study are presented in Figures 4–9 and Tables 2 and 3.

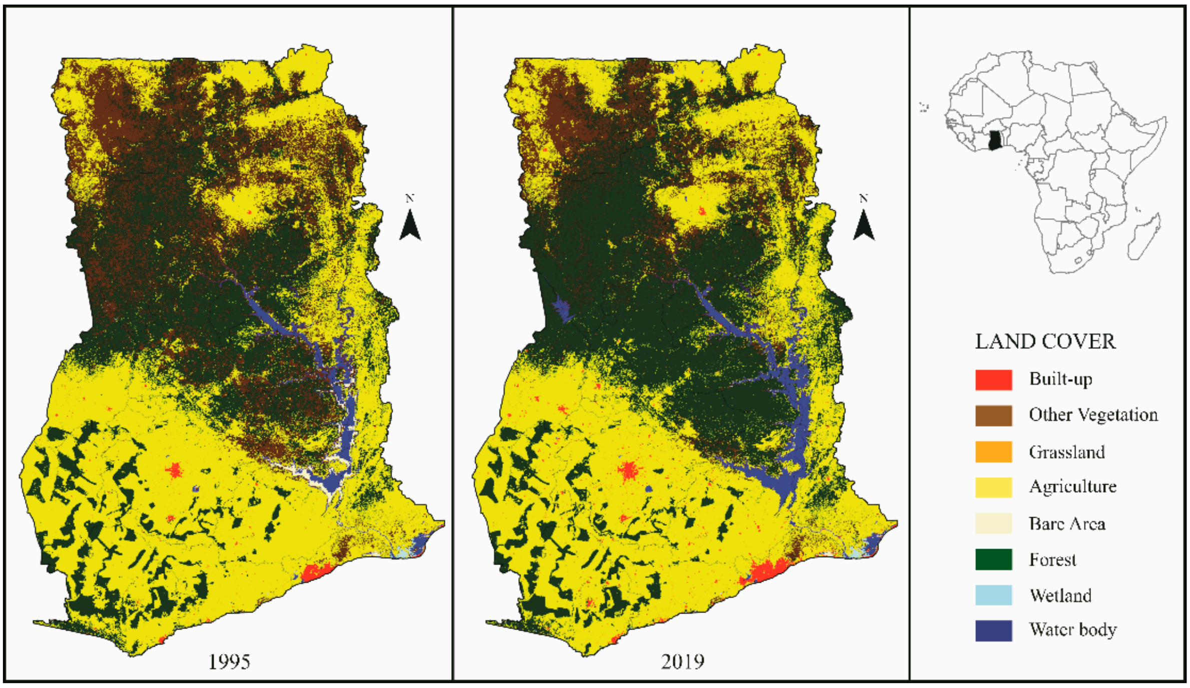

Figure 4. Land cover maps for 1995 and 2019.

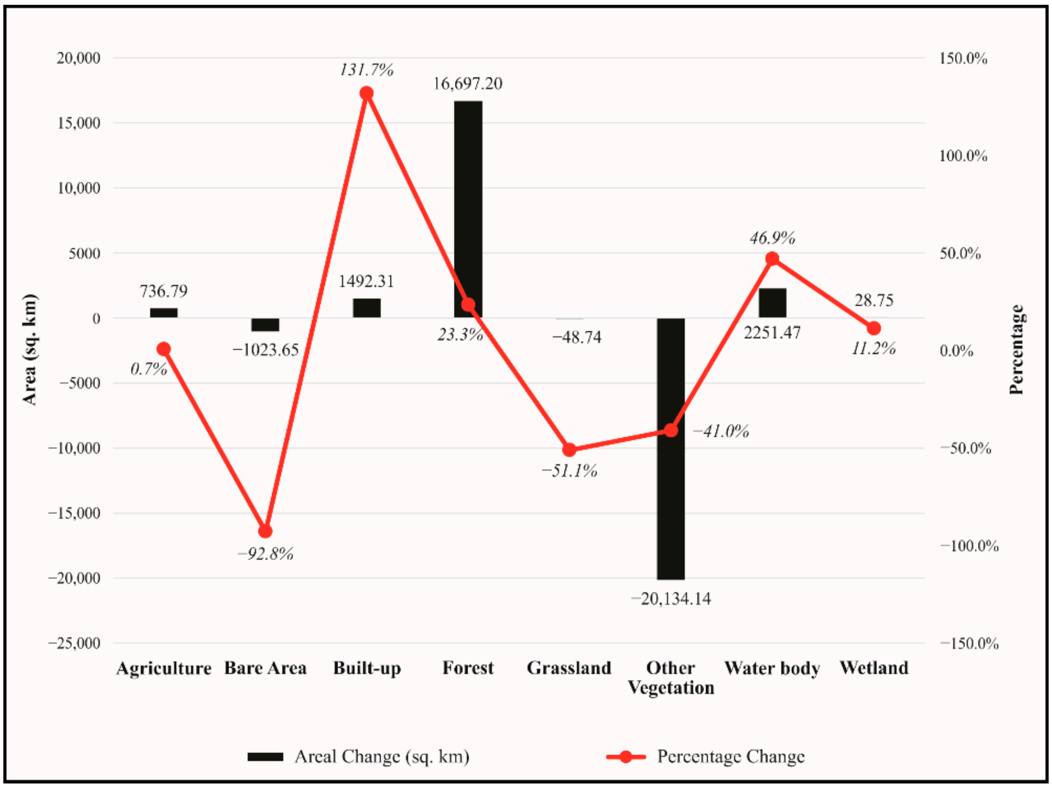

Figure 5. Area and percent land cover changes from 1995 to 2019.

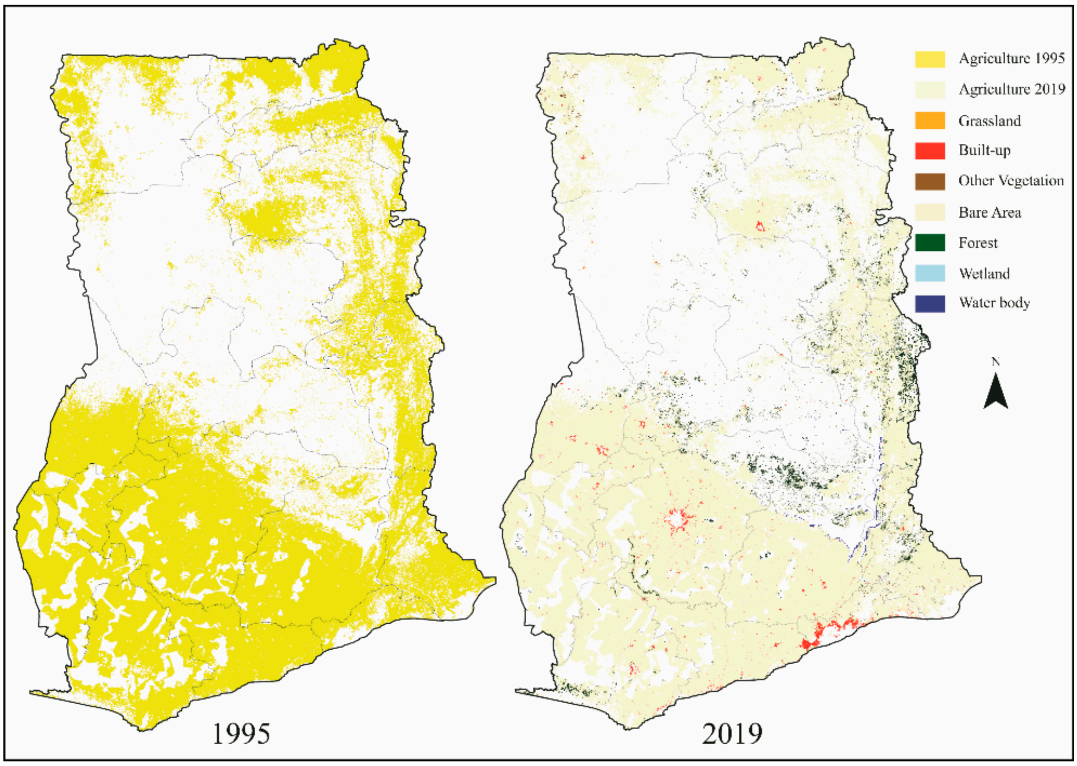

Figure 6. Agricultural land cover for 1995 and 2019.

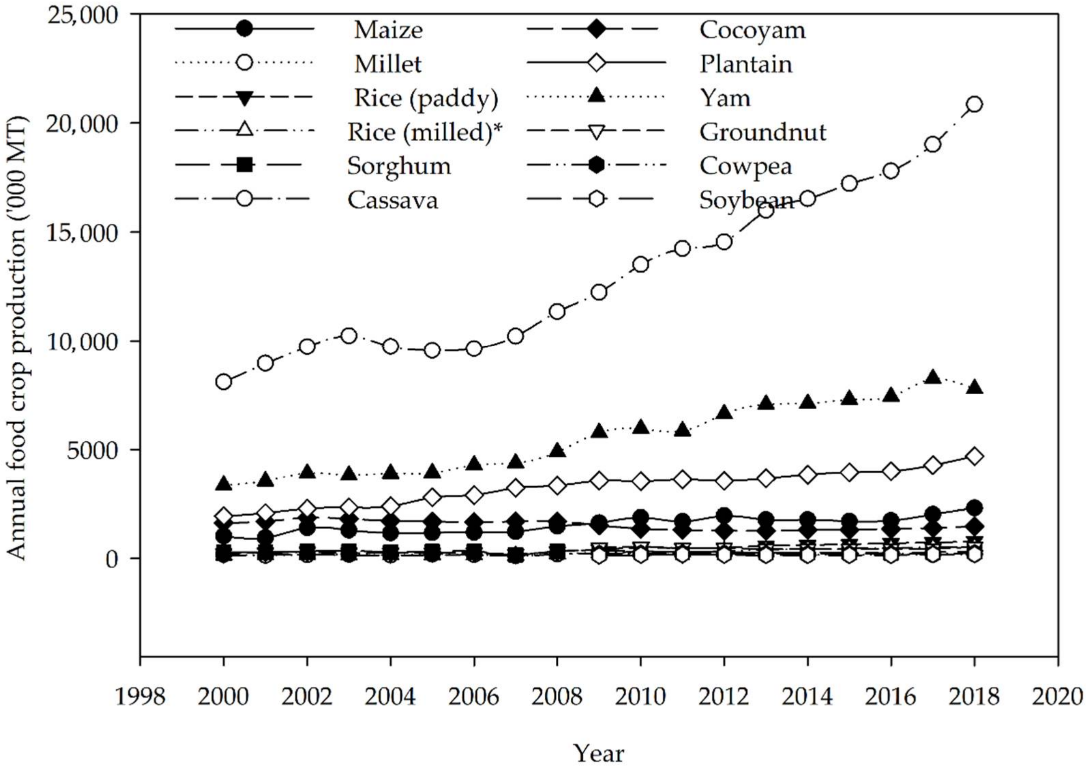

Figure 7. Annual production of major staple food crops in Ghana from 2000 to 2018.

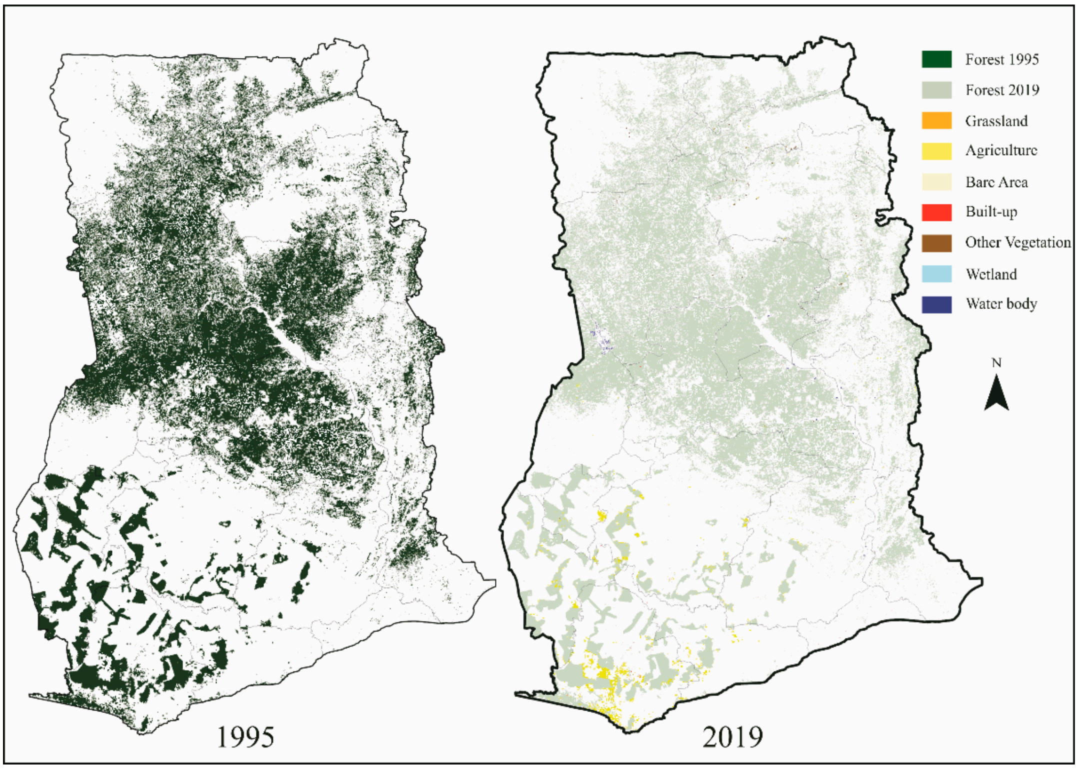

Figure 8. Forest land cover for 1995 and 2019.

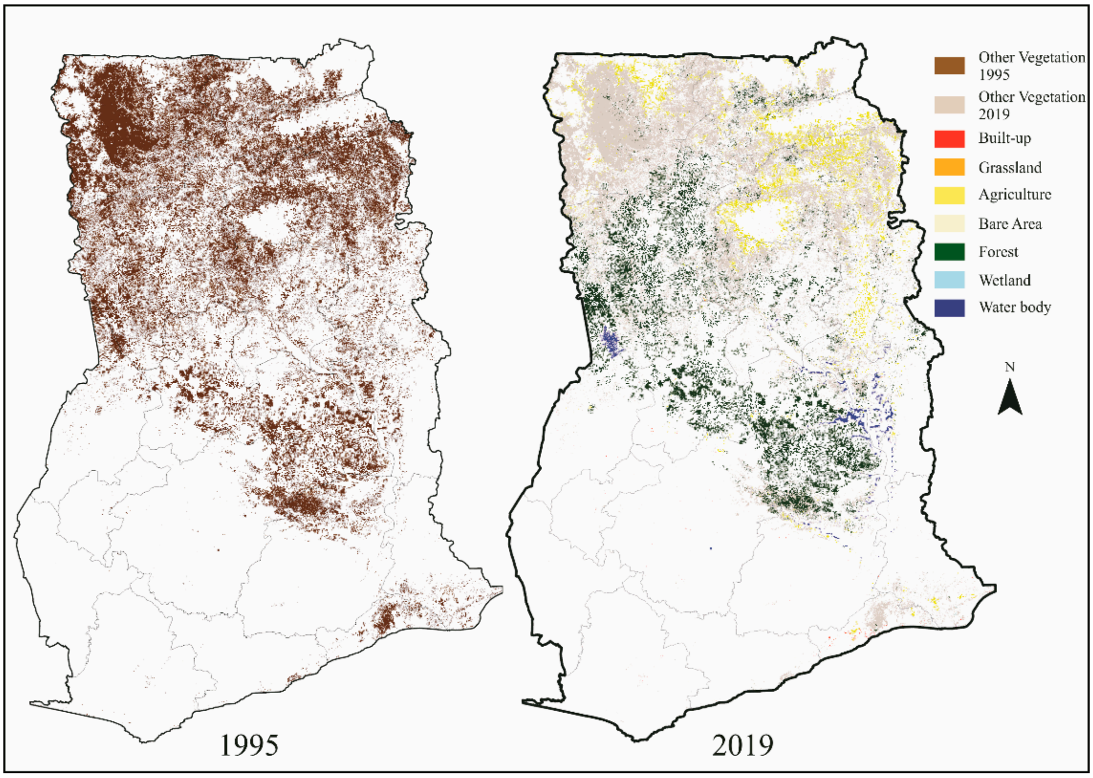

Figure 9. The other vegetation land cover category for 1995 and 2019.

Table 2. Five-year interval changes in national land cover from 1995 to 2019 †.

Land Cover	2000	2005	2010	2015	2019
			km^2		
Agriculture	993.46 (0.9) ‡	324.83 (0.3)	560.03 (0.5)	615.49 (0.5)	−1757.02 (−1.5)
Bare Area	−1034.93 (−93.8)	−8.67 (−12.7)	0.46 (0.8)	7.44 (12.4)	12.05 (17.9)
Built-up	159.53 (14.1)	373.7 (28.9)	272.87 (16.4)	352.05 (18.2)	334.16 (14.6)
Forest	6119.03 (8.6)	5181.67 (6.7)	1037.62 (1.3)	159.91 (0.2)	4198.97 (5)
Grassland	−41.06 (−43.1)	−10.65 (−19.6)	0.55 (1.3)	5.16 (11.7)	−2.74 (−5.6)
Other Vegetation	−8179 (−16.7)	−5867.14 (−14.3)	−1894.63 (−5.4)	−1395.29 (−4.2)	−2798.08 (−8.8)
Water body	1981.94 (41.3)	4.94 (0.1)	23.77 (0.4)	259.38 (3.8)	−18.56 (−0.3)
Wetland	1.04 (0.4)	1.32 (0.5)	−0.68 (−0.3)	−4.15 (−1.6)	31.22 (12.3)

† The year 1995 is the baseline; ‡ Values in parentheses are percent land cover changes.

Table 3. Changes in regional land cover from 1995 to 2019 †.

Region	Agriculture	Bare Area	Built-Up	Forest	Grassland	Other Vegetation	Water Body	Wetland
				km^2				
Ahafo	40.42 (1) ‡	0 (0)	34.88 (182.7)	−75.21 (−6.1)	−0.19 (−100)	0.09 (1.1)	0 (0)	0 (0)
Ashanti	−662.22 (−3.8)	−5.66 (−100)	301.4 (105.2)	1529.23 (30.3)	−7.04 (−85)	−1170.42 (−72.2)	14.63 (33.3)	0.09 (53.6)
Bono	−148.16 (−2.1)	0 (0)	104.62 (212.7)	490.44 (13)	−0.09 (−100)	−587.64 (−79.4)	143 (20,329,707.5)	−2.16 (−86.8)
Bono East	−545.32 (−15.7)	−65.53 (−84.8)	63.39 (1260.7)	4789.45 (35.4)	3.44 (196.9)	−4622.23 (−86.4)	368.2 (59.8)	8.6 (166.1)
Central	−92.33 (−1.1)	−3.97 (−95.5)	182.27 (307.3)	−77.09 (−9)	−6.19 (−61.3)	−0.2 (−0.3)	−1.71 (−14.2)	−0.78 (−5.6)
Eastern	−560.49 (−4.3)	−710.9 (−99)	99.43 (202.7)	1244.06 (56.9)	−24.72 (−90.3)	−984.24 (−60.6)	930.07 (81.2)	6.8 (327.5)
Greater Accra	−340.83 (−14.3)	−6.58 (−14.8)	387.67 (80.6)	20.92 (91.3)	−8.06 (−37.8)	−48.87 (−8.6)	−3.32 (−3.9)	−0.94 (−4.8)
North East	852.4 (22.9)	0 (0)	5.33 (712.6)	198.08 (10.9)	0.9 (313.6)	−1056.71 (−29.3)	0 (0)	0 (0)
Northern	1807.64 (17.1)	1 (0)	48.74 (353.8)	1287.36 (22.3)	−0.17 (−6.9)	−3168.84 (−34.7)	22.83 (7.3)	1.44 (768.2)
Oti	−947.83 (−15)	−122.79 (−91.8)	19.57 (638)	1304.15 (62.3)	2.18 (126)	−693 (−57.2)	426.37 (32.8)	11.35 (524.3)
Savannah	43.6 (2.6)	−1.69 (−81.8)	12.75 (2954.8)	5715.64 (26.9)	2.3 (447.6)	−5933.89 (−52.7)	165.71 (29.2)	−4.42 (−76.1)
Upper East	189.54 (4)	0 (0)	17.82 (454.9)	408.76 (26.1)	−0.75 (−80)	−614.92 (−24.5)	−0.47 (−2)	0 (0)
Upper West	808.7 (15.7)	0 (0)	18.14 (2426.8)	356.19 (11.4)	−1.31 (−77.8)	−1181.73 (−10.8)	0 (0)	0 (0)
Volta	−420.77 (−6.2)	−107.51 (−92.2)	51.47 (90.1)	337.87 (25.3)	−7.17 (−48.2)	−58.34 (−13.7)	192.17 (29.8)	12.26 (7)
Western	611.54 (6.6)	0 (0)	111.22 (131.8)	−704.69 (−14.7)	−1.6 (−67.9)	−8.4 (−30)	−4.79 (−16.7)	−3.29 (−11.4)
Western North	101.31 (1.5)	0 (0)	31.1 (179.2)	−132.19 (−4.2)	−0.03 (−5.9)	−0.18 (−12.1)	0 (0)	0 (0)

† The former Brong Ahafo Region was split into Ahafo, Bono and Bono East and Regions, the former Northern Regions separated into Northern, North East and Savannah Regions; the former Western Region was split into Western and Western North while the former Volta Region was divided into Volta and Oti Regions; ‡ The values in parenthesis are percentage changes in land cover.

Figure 4 shows the reclassified eight land covers for 1995, which serves as the baseline and 2019, which is the last year within the period considered for the study. In general, agricultural LC increased slightly by 0.7% from 1995 to 2019 across Ghana corresponding to about 736.79 km^2 (Figure 5). However, a periodical analysis of the change revealed that this LC increased only up to 2015 and decreased afterwards (Table 2). A regional analysis indicates that most of the increments in agricultural LC occurred in the northern parts of the country namely Northern, North East, Savanna, and Upper East and West Regions. Some increases in agricultural LC were also observed in the Western, Western North and Ahafo Regions (Table 3). However, the top four increases of 1807.64, 852.4, 808.7 and 611.54 km^2 occurred in the Northern, North East, Upper West, and Western Regions, respectively. All the other Regions lost agricultural LC (Table 3). The four Regions that had comparably higher losses of agricultural LC include Oti (947.83 km^2), Ashanti (622.22 km^2), Eastern (560.49 km^2), and Bono East (545.32 km^2). Since 1995 was the baseline year, the losses of agricultural LC are indicated on the agricultural LC map for 2019 (Figure 6). It must be noted that the decrease in agricultural land cover appears not to have translated to a decline in food production. This is because between 2000 and 2018, production of the major staple foods in Ghana either stayed about the same or increased (Figure 7).

Urban or built-up LC had a noticeable average increment of about 1492.31 km^2 across the country over the study period, representing an increase of about 131.7% (Figure 5). Gains were observed for this LC across all the time frames investigated but the highest increase of 28.9% was recorded for the 2000 to 2005 period (Table 2). The built-up area also increased in all the Regions throughout the study period (Table 3). The most gains in the built-up LC in terms of land area occupied occurred in the southern Regions of Greater Accra (387.67 km^2), Ashanti (301.4 km^2), Central (182.27 km^2) and Western (111.22 km^2) (Table 3). The growth in built-up areas in the other Regions were modest, ranging from 5.4 km^2 in the Northeast Region to 63.39 km^2 in Bono Region (Table 3). However, in terms of percentage increase, Savanna, Upper West, and Bono East Regions saw increases in this LC category above 1000%, specifically 2954.8%, 2426.8%, and 1260.7%, respectively (Table 3). Regions that experienced increases above 100% but less than a 1000% include North East (712.6%), Oti (638%), Upper East (454.9%), Northern (353.8%), Central (307.3%), Bono (212.7%), Eastern (202.7%), Ahafo (182.7%), Western North (179.2%), Western (131.8%) and Ashanti (104.62%). Greater Accra and Volta Regions showed the least percentage growth of about 80.6% and 90.1%, respectively (Table 3).

Though forest cover generally increased across Ghana and averaged about 23.3% during the study period (Figure 5), losses in the forest area occurred in some Regions, including Ahafo (75.21 km^2), Central (77.09 km^2), Western (704.69 km^2) and Western North (132.19 km^2). The rest of the Regions showed expansion in forest cover ranging from 20.92 km^2 in Greater Accra Region to 5715.64 km^2 in the Savannah Region (Table 3). The most growth was observed for the following Regions: Savannah (5715.64 km^2), Bono East (4789.45 km^2), Ashanti (1529 km^2), Oti (1304.15 km^2), Northern (1287.36 km^2), and Eastern (1244.06 km^2). These regional forest cover changes are indicated on the 2019 forest LC map (Figure 8). Gains in forest cover occurred through all the timeframes investigated but the highest additions occurred between 1995 and 2000 (8.6%), and 2000 and 2005 (6.7%). The gains for the other time frames ranged from 0.2% to 5% (Table 2).

Twelve of the 16 Regions lost grassland cover with meager increases observed for four Regions which include Bono East, North East, Oti and Savannah (Table 3). Across the country, grassland loss averaged 51.1%% during the study period (Figure 5). On the contrary, the regional gains ranged from 0.9 km^2 in the North East Region to 3.44 km^2 in the Bono East Region. Most of the grassland was lost from 1995 to 2000 (43.1%), followed by 2000 to 2005 (19.6%) and then between 2015 and 2019 (5.6%). Gains were observed for the other timeframes (Table 2).

The other vegetation LC category comprising shrubland, sparse vegetation and shrub or herbaceous cover experienced losses in 15 Regions. These losses in area ranged from 0.18 k^2 in the Western North Region to 5933.89 km^2 in the Savannah Region (Table 3). The other Regions that also lost relatively larger areas for this LC category include Bono East (4622.23 km^2), Northern (3168.84 km^2), Upper West (1181.73 km^2), Ashanti (1170.42 km^2), and North East (1056.71 km^2). Though the Ahafo Region gained 0.09 km^2 in this LC (Table 3), the area lost nationally was 20,134.14 km^2, representing a 41% loss from 1995 to 2019 (Figure 5). The changes in this LC are captured in the maps below (Figure 9). The losses were distributed across all the five-year time periods investigated. However, the most losses occurred from 1995 to 2000 and 2000 to 2005 followed by 2015 to 2019 (Table 2).

Ahafo, Bono, North East, Upper East, Upper West, Western and Western North Regions saw no change in bare area from 1995 to 2019, but Ashanti, Bono East, Central, Eastern, Greater Accra, Oti, Savannah and Volta Regions lost bare area (Table 3). The Northern Region only added 1 km^2 of bare area. Nationally, the bare area decreased by 92.8% from 1995 to 2019 (Figure 5). However, five-year interval analysis shows that most of the reductions in this LC occurred between 1995 and 2000 (93.8%) and between 2000 and 2005 (12.7%). Gains were however observed after 2005—that is, between 2005 and 2019 (Table 2).

The area covered by waterbodies increased overall across Ghana during the study period. This LC category increased by 46.9% on average (Figure 5). The most gain (41.3%) for this LC occurred between the 1995 and 2000 period (Table 2). Gains for the other time frames were much smaller however a loss of 0.3% was recorded for the 2015 to 2019 period (Table 2). While Central, Greater Accra, Upper East and Western Regions lost ground in this LC category, no change was observed for Ahafo, North East, Upper West, and Western North Regions (Table 3). Notable gains were observed in the Eastern (930.07 km^2), Oti (426.37 km^2), Bono East (368.2 km^2), Volta (192.17 km^2), Savannah (165.71 km^2), and Bono (143 km^2) Regions.

Wetland area increased 11.2% across Ghana (Figure 5) with the most significant gain (12.3%) occurring between 2015 and 2019 (Table 2). Smaller increases in the area were observed from 1995 to 2000 and 2000 to 2005, but losses in area were recorded between 2005 and 2010 as well as between 2010 and 2015 timeframes (Table 2). Five Regions including Ahafo, North East, Upper East, Upper West, and Western North experienced no change. However, Volta, Oti, Bono East, Eastern, Northern and Ashanti Regions recorded gains in the wetland area. The rest of the Regions including Bono, Central, Greater Accra, Savannah, and Western lost wetland area (Table 3).

Maps showing changes for bare area, built-up, grassland, waterbody and wetlands are not provided because the changes are not as clear on the scale used.

4. Discussion

4.1. Changes in Agricultural Land Cover

The expansion of agricultural LC observed in this study was noted in other studies as well. Previous reports indicate that agricultural LC increased from 13% in 1975 to 28% in 2000 and subsequently expanded an additional 4% to 32% in 2013 [9]. The CILSS [9] report noted that though agricultural lands increased in all the Regions, the biggest expansions were observed in the Regions located in the northeastern, east central, and southwestern parts of Ghana, which reflect the observations in this study. The growth of agricultural LC typically implies the transformation of other LC types including savannahs, woodlands, and forests to fragmented mosaics of their previous nature. The loss of agricultural land observed after 2015 was most likely due to several factors, including loss to other LC types as shown in Figure 6. In this regard, several studies [26–28,46] have reported the loss of agricultural LC to urbanization especially around the peri-urban areas, which are the areas at the interface of urban and rural areas and mining activities [25,36,47]. Kasanga et al. [48] also acknowledged the pressure on agricultural lands from other land uses in Ghana.

However, on a national scale, it appears that the loss of agricultural LC had no overall significant impacts on the production of the major staple foods, namely maize, millet, rice, sorghum, cassava, cocoyam, plantain, yam, soybeans, groundnut, and cowpea in Ghana based on the 2000–2018 food crop production data obtained from Ghana's Ministry of Food and Agriculture (MoFA) (Figure 7). This observation is in contrast with the findings of Owusu-Ansah and Smardon [47] who reported a statistical relationship between the size of mineral concessions and reduction in the production of staple crops including maize, sorghum, and cocoyam. This absence of a food production decline following the loss of agricultural LC seems to suggest that the reduction in agricultural LC is somehow being offset by increased production. The increased food production is most likely facilitated by improved or quality agricultural extension services, use of agricultural inputs (mineral fertilizers, improved seeds, pesticides), and input price subsidy by the Government. The increased production is likely coming from the Northern, North East, Savanna, and Upper East and West Regions as well as Western, Western North and Ahafo Regions, which experienced expansions in agricultural LC. This is plausible because urbanization is comparably less intense in some of these regions, especially those located in the northern parts of Ghana. Kleemann et al. [32] reported a stronger growth in urban development for Takoradi (7.1%) compared to Bolgatanga (1.1%) over a six-year period covering 2007–2013.

4.2. Changes in Urban or the Built-Up Landcover

The growth of the built LC in this context we believe comprises both urban development, which is described as the spatial expansion of an urban area in the outskirts and urban sprawl, which is defined as scattered and uneven development that occurs on non-urban land (i.e., new lots) leading to fragmentation of land [32,49]. Significant increases in the built-up LC occurred across the nation during the study timeframe (Figure 5). This LC increased during all year intervals investigated (Table 2) and in all the Regions (Table 3), indicating that more and more Ghanaians are living in cities. In fact, in a comparison of land use patterns and how they relate with land use planning in the peri-urban areas of Bolgatanga in the Upper East Region and Takoradi in the Western Region, Kleemann et al. [32] concluded that population growth was an important driver of urban development. The large expansions observed in the built-up LC for Greater Accra, Ashanti, Central and Western Regions have been attributed to rural-urban migration, globalization activities, past microeconomic policies including Ghana's Economic Recovery Program and Poverty Reduction Strategy as well as extractive industries such as crude oil which have led to increased commercial and economic activities [1,4,11,30].

In support of migration being a driving force for urbanization, Weeks et al. [24] noted that most of the north to south migration from the northern regions are typically towards Accra and Kumasi in the south. The high percent changes observed for the built-up LC are within the ranges of previous studies. Growths of 277% is reported for the Greater Accra Metropolitan Area between 1991 and 2015 [4], 70% for the New Juaben Municipality from 1985 to 2015 [30] and doubling of the area within 30 years (1986–2016) for Sekondi-Takoradi [1]. Similarly, growth rates of 4.5% and 6% were reported for Accra and Kumasi, respectively, between 2000 and 2010 [5]. The regional capital of the Northern Region, Tamale, recorded 78% expansion between 2001 and 2014 at 4.4% annual rate [50].

On a regional scale, a growth of 56% built area was reported across Ashanti, Central Eastern, and Greater Accra Regions [21]. The modest (changes in area) but rather high percentage increments observed in the built LC for the Savannah, North East, Bono East, Ahafo, Oti, and Western North Regions is most likely spurred by their designations as new regions and the infrastructure development associated with the change. While the economic opportunities and infrastructure development associated with urbanization are laudable, they typically come with negative impacts including loss of hitherto agricultural land [28,51,52], decline in ecosystem services of the land [30,53] leading to flooding and the urban heat island effect [53], water pollution and poor waste management [46] and loss of biodiversity. This urban expansion which will conceivably continue underscores the necessity for improved land management and use in and around cities.

4.3. Changes in Forest Land Cover

Forest LC is generally reported to be decreasing in Ghana by several studies and reports [9,18,33,54,55]. Therefore, the overall net gain of about 23.3% forest LC revealed by our results (Figure 5) as well as the net gains observed within the five-year intervals examined (Table 2) are contrary to previous reports. A possible reason for the disparity is that our forest LC category includes mosaic trees and shrubs, which encompass tree crops that are increasing in the area as result of Government interventions. The Government of Ghana has been supporting smallholder farmers to modernize and expand the cultivation of tree crops including cocoa and oil palm to increase acreages to meet increasing global demand and boost employment and food security locally [41,56–58]. Asubonteng et al. [59] reported an expansion of area planted in oil palm and cocoa by 11.2% and 8.9%, respectively, between 1986 and 2015 in the Eastern Region. Since both crops are grown mostly in the southern parts of Ghana, it is likely the same reason it may account for gains in the forest cover observed for Ashanti, Bono, Bono East, Oti and Volta Regions in the South (Table 3). Reforestation and afforestation programs may have also contributed to growth of the forest LC observed in some of the southern Regions. For example, there are participatory type afforestation projects being implemented in the Ashanti Region that require farmer participation [54,60].

The growth of forest LC in the Regions in the northern parts of the country including Northern, North East, Savannah, and Upper East and West Regions revealed by the LC data (Table 3) is mostly likely due to afforestation/reforestation and agroforestry programs initiated by government through the Forestry Commission of Ghana as well as Public and Private Sector partnerships including Non-governmental Organizations (NGOs) like eGRO and Form International. For example, eGRO is spearheading agroforestry projects involving the planting of cashew, mango, and Acacia trees in the Northern parts of Ghana. Similarly, Form International has partnered with local NGOs to restore and expand the shea nut tree landscape in the northern parts of the country. The Government of Ghana has also partnered with NGOs including Form International and World Vision amongst others to implement various reforestation projects across the country.

The losses in forest LC reported for Ahafo, Central, Western and Western North Regions (Table 3) are corroborated in the literature. For example, Schueler et al. [25] reported 58% deforestation within mining concessions in the then Western Region, which has been divided into the Western and Western North Regions since 2019 (Figure 1). Earlier, Koranteng and Zawila-Niedzwiecki [18] also noted that forest loss was a major issue in the Region, which is the most forested in Ghana. Osei-Wusu et al. [61] reported remarkable conversions of protected forests to other land uses in the Sefwi Wiaso District in the new Western North Region. They also projected that 877.38 ha of close forest resources were likely to be transformed to open forests and other non-forest land cover. The then Brong Ahafo Region (Figure 1) is reported to have lost 15% (137 kha) of its tree cover since 2000. In 2019 alone it lost 9.5 kha of its tree cover [62]. This Region was also divided in 2019 into three, namely Ahafo, Bono, and Bono East (Figure 1). Notable loss of forest cover is reported for the Asunafo North, Asunafo South, and Asutifi Districts, which are in the new Ahafo Region [62]. Between 2001 and 2019, the Central Region is reported to have lost 21% (158 kha) of its total tree cover, which includes 2.96 kha of its primary forest.

The losses of forest LC to other land cover types during the study period are shown in Figure 8. In general, reductions in forest LC in Ghana are attributed to the expansion of agriculture, overexploitation activities including illegal and unsustainable logging practices, extractive industries such as mining, insecurity associated with land tenure, expansion of surrounding settlements, fuelwood harvesting, and bush fires [18,25,63–65].

4.4. Changes in Grassland Cover

Grassland ecosystems (i.e., Guinea, Sudan, and Coastal Savannah) which occupy about two thirds of the land area of Ghana [8] are the second most important habitats in Ghana after the high forests—hence their degradation or loss is very significant. However, they are being degraded and lost to anthropogenic activities including, conversion to farmlands using slash and burn clearing practices, expansion of settlements, fuelwood harvesting, bush burning, and overgrazing [9,66,67]. In this study we found that about 51.1% of grassland areas across the country were lost (Figure 5). Loss of this LC was observed for three out of the five timeframes investigated in this study (Table 2). Gains were observed in the Bono East, North East, Oti, and Savannah Regions (Table 3), though losses in this LC were recorded in the remaining 12 Regions. These losses in grassland LC most likely represent conversions to other land covers while the gains represent conversions from other land covers. The degradation of the savannah area is likely accelerated by the fact that they house about 20% of the population and produce the bulk of fuelwood and charcoal (70%) in Ghana [8,68] in addition to the production of cereal grains. Braimoh [69] noted that the conversion of woodlands to agricultural lands usually led to less vegetation cover. This implies that tree removal activities in savannah woodlands could ultimately result in shrublands if not curtailed. The fact that grasslands are being lost across most Regions in Ghana most likely signifies high usage to meet human needs, which can lead to transformations to other land covers including agricultural land, other vegetation, bare land, and built-up areas.

Legal and illegal mining activities are also known for causing reductions in the grassland LC [70]. Migration to the mining areas causes an influx of people into the mining communities, leading to the expansion of the settlements and decrease in vegetation cover. Basommi et al. [15] reported a 14.3% and 5.1% decrease in open savannah and closed savannah, respectively, in the Wa East District in the Upper West region between 2001 and 2014. Basommi et al. [71] also reported a 16.8% decrease in open savannah and 50% reduction in closed savanna in the neighboring Nadowli District between 2000 and 2014. Awotwi et al. [72] reported reductions of 30.2% and 56.2% in savannah and grasslands, respectively, between 1990 and 2006 in the White Volta River basin, which covers a significant portion of Ghana and some parts of Burkina Faso. Despite migration to urban and mining areas within the savannah areas [15,50], Weeks et al. [24] determined that there is a strong correlation between the percentage of open savannah in the northern part of Ghana and outward migration to southern part. This observation suggests that sustainable management of the open savannahs could mitigate the north–south migration in Ghana, which is causing expansion of southern cities such as Kumasi and Accra.

Wildfires are also a contributor to the loss of savannah vegetation [71,73]. The effects of wildfires, farming activities, and fuelwood extractions are likely exacerbated by the vulnerability of savannah areas, which are predominant in the northern parts of Ghana to climate change and variability as well as extreme climate events including erratic rainfall patterns, dry spells, and high temperatures [74–76]. Amoako et al. [77] reported that fire, which is a very common tool used to burn bush to stimulate growth of fresh forage for livestock, land clearing, wild honey hunting, and for game hunting activities in the savannah areas of Ghana, has negative consequences on vegetation. They also determined that burning has a negative effect on tree density when they investigated the impacts of seasonal burning on tree species in the Guinea Savannah Woodland in the Mole National Park.

4.5. Changes in Other Vegetation Cover

The other vegetation land cover category in this study includes sparse vegetation, shrubland, and/or herbaceous cover (Table 1). It decreased by 41% nationally over the study period (Figure 5) and showed losses across all the five-year timeframes examined (Table 2). These losses are also reflected across the Regions (Table 3). Since this LC is interspersed among the other land covers across the country (Figure 9), changes observed for this LC are inherently linked to changes in the other land covers including agriculture, built-up, forest, grassland, bare area, wetland, and waterbody. The losses observed across the country indicate conversion of this LC into other land covers over the study period.

4.6. Changes in Bare Area

Bare area decreased significantly over the study period (Figure 5). It reduced the most between 1995 and 2000 but increased between 2005 and 2019 (Table 2). While seven Regions saw no changes in this LC, eight Regions lost bare area with only one Region (Northern) recording a meager gain (Table 3). Bare area similar to the other vegetation LC is spread amongst the other land covers, and therefore its expansion or contraction is linked to changes in the other land covers. Reductions [4] and increases [78] of bare area is often associated with urban development as well as conversions from other land covers such as savannah [15,71]. Hence the losses reported represent changes to other land covers such as the built-up LC, while gains indicate transformation from other land covers as mentioned above for the savannah LC.

4.7. Changes in Waterbodies

Water resources in Ghana include the Volta River Basin, which drains 70% of the country from north to south and the South-Western River Systems comprising the Bia, Tano, Ankobra, and Pra Rivers as well as Coastal River Systems consisting of Ochi-Amissah, Ochi-Nakwa, Ayensu, Densu, and Tordzie/Aka Rivers. The Volta River has major sub-basins including the Black and White Volta Rivers, the Oti River, and the Lower Volta as well as Lake Volta. The water resources also include the freshwater lake, Lake Bosumtwi, and impoundments and reservoirs including Lake Volta and the Kpong Headpond on the Volta River and the Weija and Owabi Reservoirs on the Rivers Densu and Offin, respectively [79]. The water levels in these water bodies vary with the season and year depending on rainfall and drought conditions [79].

In this study we found that there was a net 46.9% increase in the area covered by water bodies across the country (Figure 5). Increments were observed for all the timeframes examined except for the 2015–2019 period. However, the largest increase occurred between 1995 and 2000 (Table 2). Varied changes in this LC were also recorded for the Regions (Table 3). While Ahafo, North East, Upper West, and Western North Regions recorded no change, Ashanti, Bono, Bono East, Eastern, Northern, Oti, Savannah, and Volta Regions saw increases in waterbody cover. Central, Greater Accra, Upper East, and Western Regions experienced reductions in their waterbodies during the period (Table 3).

The changes observed for this LC are most likely a reflection of the spatio-temporal variation, distribution, and amounts of rainfall as well as other climatic conditions in the Regions. In respect to this, Kankam-Yeboah et al. [80] determined that stream flow in White Volta and Pra Rivers Basins were sensitive to changes in rainfall and temperature. However, the 143 km^2 gain observed in the Bono Region is likely due to the construction of the Bui dam on the Bui gorge. The construction of the dam created 444km^2 of the new water area [81], which is about 19.7% of the of 2251.47 km^2 net gain of water expanse revealed in this study. Recent studies however predict reductions in rainfall and therefore water resources in some of the major river basins in Ghana under future climate scenarios [82,83]. Water quality in the river basins is also being impacted by LULC changes including agricultural and illegal mining activities [84–86]. Collectively these observations suggest that addressing future changes effectively will involve better planning, management, and monitoring of water resources.

4.8. Changes in Wetlands

Wetlands are defined as "areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporal, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters" [87]. In Ghana, wetland ecosystems form about 10% of the country's total land surface and are categorized into three major types namely marine/coastal, in-land, and man-made [88]. Marine/brackish wetlands include Keta Lagoon Complex, Songhor, Sakumo, Muni lagoons and the Densu Delta, which have Ramsar site designations. Other important wetlands include the Amanzuri, Ehulu, Korle, Kpeshie, Butre, Fosu lagoons as well as the Ankobra and Whin estuaries [89]. Ghana also has a freshwater inland wetland, which is a Ramsar site called the Owabi Wildlife Sanctuary.

Though there are reports of threats and decline in wetland resources in Ghana [90–92] not much quantified information exists on the national scale. The results of this study show a net increase of 11.2% overall in wetland cover (Figure 5). This LC increased in area from 1995 to 2005 and declined in area thereafter until 2015 but the loss in area was bigger between 2010 and 2015 timeframe (Table 2). This signifies an intensification of the factors responsible for the change during that period. Similarly, the gains observed after 2015 could be an indication of some level of curtailment of these drivers. Ekumah et al. [93] also found time interval changes for Densu Delta, Sakumono II and Muni-Pomadze Ramsar Sites.

Most of Ghana's wetland resources occur in the south and in coastal areas. As such, it is not surprising that Regions such as Ahafo, North East, Upper East, Upper West, and Western North East recorded no changes in wetland area (Table 3). The increased wetland cover recorded in the Volta Region over the study period is likely the result of interventions by conservation programs. The losses in wetland cover in the Greater Accra and Central Regions are likely due to anthropogenic factors. Ekumah et al. [93] also reported losses in area for the Densu Delta and Sakumono II (Greater Accra Region) as well as Muni-Pomadze (Central Region) Ramsar Sites between 1985 and 2017. They attributed the decline in the two Ramsar Sites in the Greater Accra Region to rapid increases in the built-up LC (i.e., urbanization) and that at the Muni-Pomadze Site to combine urbanization and agriculture. Though a loss in wetland cover was not observed within the study period for Ashanti Region, there are reports of wetlands being converted into built-up areas in Kumasi, the capital, because of competing interests in land in the city. These activities have increased the potential and frequency of flooding as well as surface runoff in wetland areas [94].

5. Opportunities for Sustainable Land Use and Development

In the past 50 years, human activities have affected 83% of the global terrestrial land surface and have damaged 60% of ecosystem services. LULC changes have been the lead indicator of the human footprint and the most significant driving force behind land degradation and loss of biodiversity [95]. It is obvious from the above discussions that changes in LC have tremendous impacts on the various land and water resources Ghanaians depend on for their livelihoods. While these LC changes have negative impacts and pose serious challenges, they present unique opportunities for developing more sustainable paths for the use of Ghana’s natural resources. These opportunities can be grouped into four broad categories namely building the capacity of Government Institutions to improve enforcement of existing laws, improving land use planning, agricultural (crop production) intensification, and expanding education and outreach activities.

Since population growth and its associated effects on the demand for food and fiber, settlements, water, forests, and other natural resources is major, successful sustainable development strategies must be multi-faceted and integrated and include empowering government agencies. This is because poor implementation of existing laws is reported in the literature [32] as a problem pertaining to managing Ghana’s resources. It is important that Government Agencies are empowered to effectively enforce existing laws. In addition, laws should also be revised, if necessary, in collaboration with stakeholders to meet changing needs. Similarly, new policies should be developed with stakeholder input where they are lacking. Under-resourced agencies and shortage of trained personnel were identified as major issues affecting the management of Keta and Songor Ramsar Site [90]. As such, Government Institutions with oversight responsibilities over the various sectors should be fully resourced and fully trained to deliver their mandates. Additionally, with respect to Government Agencies, Armah et al. [96] noted that in general, the roles and responsibilities of the Institutions overseeing natural resources management in Ghana are unclear. In the same vein, Kondra [91] observed a lack of clarity on the assignment of management roles regarding wetland management and protection in Ghana. This is because though the Wildlife Division of the Forestry Commission is designated as the lead outfit for wetlands management, several different institutions including the Centre for African Wetlands, the Council for Scientific and Industrial Research, the Environmental Protection Agency, the Volta River Authority, the Irrigation Development Authority, the Water Resource Commission, district, municipal and municipal assemblies, and NGOs are involved. Hence, eliminating such ambiguities by assigning clear roles to stakeholders will be necessary to achieve expected management and protection results. Similar to wetlands, water resources management in Ghana involves 10 institutions including the Forestry Commission, Water Research Institute, Ghana Water Company, Organizations Producing Portable Water, Hydrological Services Department, Volta River Authority, Irrigation Development Authority, Minerals Commission, Ghana Meteorological Commission, and Environmental Protection Agency [97].

Success in such a multi-institutional collaborative management effort of water resources, requires assigning clear roles, good coordination, clear communication, and strong collaboration. In addition, such cooperation and level of communication needs to be extended to Government Institutions in charge of agriculture, forestry, mining, and urban development. This is because the health of water resources is intricately linked to what happens on land with respect to agriculture, forests, savannahs, mining activities and human settlements. For example, degradation of agricultural and forestry lands due to poor use and management can lead to sedimentation of surface water resources and their pollution. Besides impacting the quality and use of the water resources, drainage from polluted rivers can lead to pollution of estuaries and wetlands, leading to their deterioration and poor ecological functioning. Similarly, poorly planned urban development can seriously alter the hydrology of urban areas and lead to increased surface runoff, frequent flooding, pollution, as well as the deterioration of other land covers such as wetlands, as reported in the literature for Accra, Kumasi, Sekondi-Takoradi, and Tamale [94,98] and coastal wetlands in the Greater Accra and Central Regions [93].

Expansion of the built-up LC is currently prominent and is expected to increase in areas with population growth—hence, the importance of improving land use planning in urban areas cannot be overemphasized. It appears the current public perception is that land use planning in Ghana is dysfunctional. It is engulfed in several challenges and therefore not working as anticipated. Prominent amongst these challenges are poor enforcement of legal regulations, customary land tenure, disengagement of citizens in the planning process and institutional holdups [30,32]. Ensuring the independence of land management institutions can help streamline policy challenges, minimize duplication and intersecting roles, and enhance sustainable development of urban areas in Ghana [30,99]. An efficiently functioning land management system can address the current fragmented and haphazard pattern of urban expansion [1,5,32]. An effectively operating system can also facilitate and oversee the transitioning of city expansion to a more compact and vertical growth structure to make urban expansion more sustainable and reduce further engulfing of peri-urban landscapes by cities. Such transformation should make adequate provision for green spaces or greenbelts, drainage infrastructure, and include green technologies as well.

Matching the food needs of the growing population will require intensification of agriculture—especially crop production. To be fully effective, improvements in crop production must encompass the traditional systems and areas as well as peri-urban areas. In this regard, it is important for producers and stakeholders in agriculture to adopt sustainable intensification practices that improve soil health and environmental quality. Crop and soil productivity can be enhanced through the integrated use of organic and inorganic fertilizers, the use of improved seeds (disease/stress resistant and higher yielding varieties) and herbicides. Similarly, farming systems need to be realigned to help mitigate the effects of climate change on land use. The promotion of diversified farming systems such as cover cropping, intercropping, crop rotation, mixed cropping, and agroforestry systems that improve soil and environmental quality should be encouraged. Annual burning of vegetation covers for game, fodder for livestock, and crop production in the savannahs (grasslands), forest and wetlands needs critical reassessment by all stakeholders. This is because burning vegetation cover promotes soil and environmental degradation, leading to a change in vegetation cover and global warming. Adopting conservation agricultural practices such as reduced tillage or no- till would also help minimize soil degradation in the savannah and the forest areas where most food crops are produced. This is because land preparation using conventional tillage techniques destroys soil structure, soil aggregation, soil carbon storage leading to the erosion of the top productive soil layer by water and wind [100]. Land degradation itself presents opportunities for afforestation. Adoption of these suggested improvements coupled with enhanced water management techniques can make farming systems more sustainable and climate resilient.

On the peri-urban front, sections of established green spaces can be designated for crop production. That will provide an avenue for peri-urban farmers to function and curtail the current situation in which they are completely outcompeted and displaced by competing land use interests such as residential and commercial real estate development [26,51]. In addition, training programs need to be instituted to equip peri-urban farmers with alternative crop production techniques. Such trainings should introduce farmers to urban crop cultivation approaches including the use of raised beds, vertical growing, indoor and greenhouses. These activities could significantly contribute to the production of fresh produce and improve food security in urban areas.

There are reports of both policy makers and citizens being oblivious of the relevance of certain resources and hence the need for protecting them [90,91]. Rectifying this through awareness creation will require expanding education and outreach programs targeting multiple audiences. These programs could be conducted by the responsible Government Agencies alone or in partnership with Private Institutions and NGOs. To be effective, such educational activities should be supported with locally generated data. Currently, since there is a paucity of that [21], it is necessary for the Managing Institutions to be resourced and provided the tools to facilitate the collection, curation, and supply of relevant data. This will tremendously boost the success of educational activities and improve peoples' understanding of the importance of wise use of resources and the interlinkages between their activities and sustainability of the resources they depend on. In addition, it will encourage civic engagement and participation in resource management issues and programs.

6. Conclusions

Sustainable management and the use of natural resources are essential for ensuring their availability for posterity. Hence, it is a matter of serious importance and must be a concern for everyone. This study is one of a few of its kind and provides a country-wide overview of LC changes over a period of almost a quarter-century to highlight changes including suggestions for addressing the challenges noted. Studies such as this one are very important because of population increases and the continued extraction of resources leading to environmental issues, which need attention. Hence, knowledge of the magnitude of LC changes and the challenges posed as result, as well as their causes is necessary for developing effective solutions. The results of this study suggest that most of the LC changes observed over the study period appear to be influenced largely by agricultural activities and urbanization, both of which are boosted by population growth. Though not examined directly, it was inferred from the literature that extractive activities such as mining and unsustainable forest management practices are contributing to the dynamics of the LC changes observed.

The study also revealed the changes in the various land covers varied within the periods investigated. This indicates that the intensity or cumulative effect of the driving factors are in flux as well. This observation opens an opportunity for understanding the dynamics of these elements to better address undesirable trends on time.

All the land covers studied are interconnected because they exist in the same broad landscape of the country. Given that the management of these land covers often falls on the shoulders of several different Government Institutions, strong joint efforts including clear role assignment, coordination, and communication are needed for effectiveness. It is also necessary to empower, fully staff, and equip all Government Units with oversight responsibilities over these resources.

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