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Detection and evaluation of long-term Land Use/Cover Changes using Landsat satellite data. A case in the Ahafo Ano Southwest District of Ghana

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Abstract

This study examines Land Use and Land Cover (LULC) changes over a 30-year period (1994–2024) in the Ahafo Ano Southwest District of Ghana using Landsat imagery from 1994, 2004, 2014, and 2024. Supervised classification based on the Maximum Likelihood algorithm was applied to classify the images into five LULC categories: dense vegetation, sparse vegetation, wetland, bare land, and built-up area. The classification results achieved overall accuracies above 95% with Kappa coefficients of approximately 0.92. The results indicate a substantial expansion of built-up areas, sparse vegetation, and bare land, occurring at the expense of dense vegetation and wetlands. These changes are primarily associated with increasing human activities, particularly agricultural expansion and urbanization, which corresponds with population growth in the study area. The findings provide important insights for land-use planning and the formulation of sustainable development policies aimed at enhancing forest cover, conserving ecosystems, and mitigating carbon stock loss.

Highlights for public administration, management and planning:

- This study found that uncontrolled agricultural and settlement expansion drives forest and wetland loss, calling for stronger land-use regulation.
- We suggest integrating remote sensing and GIS-based monitoring systems into district planning to track land cover change effectively.
- The recommendation is to promote reforestation and land rehabilitation programs to restore degraded ecosystems and enhance carbon storage.
- We advise developing population and resource management strategies that balance urban growth with sustainable land use practices.

Keywords

Land use,
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1 Introduction

The world's land cover faces alarming depletion and loss due to deforestation and forest degradation (Kyere-Boateng & Marek 2021). Land around the globe provides a wide variety of benefits (Löf et al. 2019) that provide critical and diverse services and values to human society (Jenkins & Schaap 2018). These include services that support a comfortable and safe environment playing an important role in the global carbon cycle. (Schimel 1995; Millenium Ecosystem Assessment 2005; Richards et al. 2022). Lands have provided a multitude of services and benefits that contribute to human survival and quality of life (Wangchuk et al. 2021). Land provides natural products, supports life, and provides other services for man (Weldetnsae 2021). Through the uptake of CO_2 from the atmosphere, land plays a central role in the global carbon cycle since it influences the exchange of energy, water, and momentum between the atmosphere and the land surface (Pongratz et al. 2009). These are essential for the survival of all life on the planet earth and the welfare of humanity (Hassen et al. 2023; Lhoest et al. 2019). Human well-being and progress toward sustainable development are vitally dependent upon the earth's forested lands (Moutouama et al. 2019). Studies have shown that forests are a major contributor to carbon cycling and greenhouse emissions (Hurteau 2021) providing a wide range of benefits to human societies (Wangchuk et al. 2021), produce and conserve soils, stabilize stream flows and water runoff, prevent land degradation and desertification, and reduce the risks of natural disasters such as droughts, floods, and landslides (Jenkins & Schaap 2018). These have contributed to biogeochemical cycles of elements, which enable them to mitigate climate change impacts, soil erosion regulation, resilience, pollination, and water and soil protection (Djomo Cédric et al. 2023).

Over the last 50 years, land cover change have gained strong recognition from civil society for their importance, not only for the environment but also for human beings (Bruzzese et al. 2022). As a result, its approach has undergone significant theoretical and methodological development in the last two decades and has become widely used to inform policymakers and land-use managers of the links between ecosystem functions and human wellbeing (Cuni-Sanchez et al. 2019). This was introduced to raise public awareness of the importance of biodiversity for human existence and to conserve biodiversity (Mengist & Soromessa 2019). Forested land is thus acted as a very important source of emissions, as a result of logging and burning, and also as a carbon sink, since they have taken in much of the extra carbon added to the atmosphere (Mitchard 2008).

This is expected to provide livelihoods and food security to the world's rural poor (Kyere-Boateng & Marek 2021). Goods from land provide an important hidden harvest for rural populations, keeping many people out of extreme poverty (The World Bank 2023). Lands have provided society with a multitude of values in the form of both private and public goods. These values are thought to contribute vital support to providing benefits needed to maintain human populations (Reed et al. 2017).

As a result, land management should be assessed and optimized to consider all positive and negative side effects and increase its overall contribution to the collective well-being of mankind (Pisani et al. 2022). Despite land being known to be significant to the delivery of significant services, they are one of the most threatened physical features worldwide (Eyassu 2021). Land has being converted to other uses (Haywood & Henriot 2019) experiencing increased selective exploitation of important indigenous species (Bussmann 2002). Man's activities on the land usually affect changes on its cover and are the necessary basic elements for environmental concern which are gaining popularity as the primary source of global environmental change (Yang 2001; Dadson & E. 2016; Mengitu & Salami 2018). Deforestation and land degradation set off a series of environmental changes that significantly reduce the valuable services affecting global biodiversity (Kumar et al. 2022). Population growth and an increasing demand for natural resources to meet developmental needs have led to an unprecedented destruction of lands (Antwi-Agyei et al. 2019). Inadequate land management is one of the factors contributing to the detrimental human effect on urban and suburban lands (Pedrotti 2013). The extent of degraded land across the globe illustrates the need for restoration projects, with major investments of time and resources spent on reforestation efforts (Vardon et al. 2019; Stanturf et al. 2014). These have undermined the ability of the biophysical environment to sustain human beings and their livelihoods (Isaksson et al. 2018; Costanza et al. 2014), threatening the survival of many species and reduced the ability of land to provide essential benefits i.e., clean air and water, healthy soils for agriculture, and climate regulation. Africa's extraordinary richness in biodiversity, and wealth of indigenous and local knowledge, comprise a strategic asset for sustainable development in the region (Vardon et al. 2019). The continent's lands are known to provide goods and services to local people and therefore constitute the basis of their socioeconomic and cultural development (IPBES 2018; Moutouama et al. 2019; Grêt-Regamey et al. 2017). These services are usually categorized into supporting, provisioning, regulating, and cultural, which include all types of physical goods and non-extractive benefits from the environment (Wangchuk et al. 2021). These are generated by the ecosystem that provide utility to people's well-being (Tamire et al. 2023). Studies have shown that economically challenged rural communities living near forests significantly depend on their land (Hong & Saizen 2019). The role of land cover as a disaster control agent is very well recognized in a study conducted by (Obeng et al. 2019). This is commonly perceived by populations whose members are not directly involved in land use activity (Swinton et al. 2007; Díaza et al. 2011; García-Llorente et al. 2011). These show that land has provided several significant services that have contributed to the well-being of people (Lakerveld et al. 2015; Kotula 2022).

Although billions of people worldwide are estimated to satisfy at least part of their basic needs by using nature, we still lack adequate information on how much it is used (Fedele et al. 2021). It should therefore be noted that land resources availability and presence in an area do not guarantee benefits for all people (Adams et al. 2020), since intensive dependence on these resources causes degradation that may lead to the loss of carbon particularly unsustainable utilization of land resources (Hong & Saizen 2019). Research scientists are of the view that changes in the composition of the atmosphere are a result of loss of land cover change induced concentration of greenhouse gases such as CFCs, carbon dioxide, and methane among others, and have contributed to global warming affecting the livelihoods of people (Mngumi 2016). This is usually a result of anthropogenic activities that increase the concentration of greenhouse gases in the atmosphere (i.e., ozone, methane, carbon dioxide, etc). When greenhouse gases combine, they form a compound called carbon monoxide, which causes ozone layer depletion and global warming.

This is of particular importance in sub-Saharan Africa where the majority of households depend on land-based activities for their living (Antwi-Agyei et al. 2019). It is worth noting that changes in land use will have profound impacts on GHG fluxes (Rounsevell & Reay 2009), and information on carbon cycle potentialities and carbon stock changes of tree crop monoculture systems in Africa are scarce and incomplete (Grieco et al. 2024). It is undeniable that ecosystems' resilience, forest resource protection, and mitigation potentialities are interlinked with socioeconomic improvements but more research is needed to properly assess the actual impact of forest reduction on carbon (Grieco et al. 2024). As a result, it's vital to understand that human land use change is a substantial concern for climate change and livelihoods (Adjei et al. 2014; Antwi-Agyei et al. 2019).

According to recent studies, when humanity's ecological demand exceeds its supply it assumes a phenomenon called ecological overshoot (Wackernagel et al. 2002). This ecological overshoot is what leads to LULC changes (Peters 2019). Probably one can say, that one of the most important changes in global environmental change is LULC change since it occurs at spatiotemporal bases relevant to our existence (CCSP 2003). These have contributed to complex processes that have not only affected forest cover but also drove climatic changes.

Ghana, like any tropical forest developing country, is not immune to human-caused deforestation and forest degradation (Kyere-Boateng & Marek 2021). Ghana's forest and its products account for about 3% of the Gross Domestic Product and contribute about $240.9 million in terms of the overall value of exports (Tuffour-Mills et al. 2020). In terms of employment, the forestry sector offers about 13 million jobs to people worldwide (Arce 2019). Besides direct employment, the forest is a major source of livelihood for 1.6 billion people around the globe (FAO 2016). 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 the need for action (Ampim et al. 2021). The country's population has grown from about 5 million during independence in 1957 to 31 million in 2020 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 (Ampim et al. 2021). 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 (Service 2010). Forest ecosystems, national parks, and forest reserves do not meet the expectations regarding the ecological function they are to perform despite several efforts made to protect these resources (Oduro Appiah et al. 2021). The conversion of forest areas into agricultural lands and pastures and the global expansion of commercial agriculture or agribusinesses (e.g., cattle ranching, soybean farming, and oil palm plantations) have led to high levels of tropical deforestation which has caused a drastic loss of ecosystems (Shimamoto et al. 2018; Dahan et al. 2023).

Forests and trees in Ghana are in many ways impacted by land use change, and they influence climate. Hence, Ghana's forests and trees are increasingly becoming strategic in addressing climate change, as captured in African countries' Nationally Determined Contributions (NDCs)(African Forest(Africa Forest Forum 2022). These changes are most common in forest districts of the country where land resources are extracted as a result of land-based activities(Antwi-Agyei et al. 2019; Adom et al. 2024). In 2010, the Ashanti region of the country had 1.51 Mha of natural forest, extending over 61% of its land area. In 2023, it lost 26.0 kha of natural forest, equivalent to 18.7 Mt of CO_2 emissions (Global Forest

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Watch 2024). The region's worst affected lands are Apamprama, Subin Shelterbelt, and Oda River Forest Reserves (Arthur-Mensah 2023). The Amansie district of the region has also experienced significant changes in land cover due to the intensification of tropical hardwood logging (Asiedu et al. 2023). This is of no exception to the Ahafo Ano Southwest district in Ghana where land based activities such as artisanal gold mining (locally known as galamsey and deforestation/forest degradation) have been affecting the land (Anim-Gyampo et al. 2021; AASWDA 2025). The district is known for extensive illegal artisanal gold mining operations due to the widespread gold deposits (Anim-Gyampo et al. 2021). This has led to an influx of various majority people of which are youth from different parts of Ghana (Anim-Gyampo et al. 2021). According to studies, the population of the districts has kept increasing at an alarming rate over the years (Republic of Ghana 2019). This has contributed to large wood exploitation as well as the conversion of more forest lands into subsistence farms and cash crop plantations (Atampugre et al. 2022). Forest reserves have been encroached upon by farmers, sand winners and illegal chain saw which has led to vegetation clearance (Cocoa & Forest Initiative 2023). The primary vegetation is rapidly being replaced by secondary forest. This is a result of excessive and careless tree cutting, mainly by illegal chainsaw users. Inadequate farming methods such shifting cultivation, unchecked bushfires, and sand-winning activities also contribute to the forest's depletion (Baidoo & Obeng 2023). In 2020, Ahafo Ano South had 48.0 kha of natural forest, extending over 40% of its land area. In 2023, it lost 1.57 kha of natural forest, equivalent to 1.50 Mt of CO_2 emissions (Global Forest Watch 2024). These changes could have impacts on carbon carbon storage and sequestration capacity in the district ecosystems since 8.55 Mt of carbon has emitted into the atmosphere between 2001 and 2024 (Global Forest Watch 2024). Therefore, it is necessary to embark on this study to bring to the awareness of the general public about land use changes because human activities, such as urban development and agriculture, significantly alter the physical landscape, leading to consequences like soil erosion, water quality degrading, loss of wildlife habitats, and changes to climate patterns, which impact both the environment and human health (Nedd et al. 2021; Wang et al. 2020).

Since researchers can determine patterns of LULC change, evaluate the effects of socioeconomic policies on land use, and optimize management strategies, studying this is essential for comprehending the dynamics behind human-nature interaction (Liu et al. 2025). By offering scientific foundations for the creation of effective land management plans, resource optimization, and policies that support sustainable development goals, LULC studies assist in informing decisions about conservation, urbanization, and agricultural expansion (Chang et al. 2018; Liu et al. 2025; Winkler et al. 2021).

Remote sensing and GIS as an essential technologies will be employed for the study since they are materials for creating and understanding the natural and physical processes at the world's surface (Pei et al. 2021). Remote sensing has been considered as a quick and valuable tool for accurately documenting changes in LULC on regional and worldwide levels whilst GIS offers a multipurpose platform for gathering, preserving, displaying, and examining digital data required for identifying changes and constructing a database. Remote sensing technologies and GIS provide a scientific foundation for understanding and managing land-use change, serving as crucial tools for monitoring and assessing change over time (Baidoo & Obeng 2023). The remote sensing considers the most technique used through among many techniques for change detection, because of its cost-effectiveness and time-saving characteristics (Sameer & Hamid 2023). Images obtained by remote sensing contain rich spectral information, which has always been essential data in land cover and land use research (Digra et al. 2022; Zhao et al. 2022). Therefore, the study adopts these technologies to detect and evaluate Long-term LULC changes in the Ahafo Ano Southwest District to assess the usefulness of the tool in monitoring and analyzing LULC in the study area. This will provide vital information for sustainable land management, environmental monitoring, and policy development, revealing how human activities and natural processes impact resources, climate, and ecosystems (Raffay et al. 2025; Baskent 2021; Nakhle et al. 2024).

The main aim of the study is to establish a comprehensive baseline assessment of the Ahafo Ano Southeast's LULC using satellite datasets, focusing on key indicators such as land use change patterns and its impact to understand the current state of the environment. Specifically, the research aims to Analyze and quantify the pattern of land cover change and associated land use in the Ahafo Ano Southwest district in Ghana between 1994 to 2024.

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2 Materials and methods

2.1 Study Area

The area falls within the wet semi-equatorial climatic region of Ghana, which is characterized by the occurrence of two rainy seasons. The major season occurs between March and June while the minor season spans September to November (Dzepe et al. 2024). It lies between longitude 1°45′W and 2°20′W and latitudes 6°42′N and 7°10′N. The District shares boundaries with four districts, in the North with Ahafo Ano South-East District, Atwima Mponua District to the South, Atwima Nwabiagya Municipal to the East and Ahafo Ano North Municipal to the West all in the Ashanti Region. The location of the District falls within the forest zone of Ghana (Republic of Ghana 2019).
This district (Fig. 1) was initially known as Ahafo Ano South District. It is located in the northwestern part of the Ashanti Region (Adduow 2015). The district has a land mass of about 1 241 km², occupying 5.8% of the total landmark of the Ashanti region with the district capital Mankraso located 34km along the Kumasi-Sunyani Highway (Adduow 2015). The district has fertile humus soil covered with forest which makes it ideal for major farming activities such as cocoa farming (Adduow 2015). Twenty-eight (28%) of the total land area is covered with forest trees making the soil moisturized (Adduow 2015). Agriculture plays a very significant role in the employment and income of the people living in the above-mentioned districts. Agriculture alone employs an estimated 70.2% of the working population in the Ahafo Ano South West district (The Ministry of Finance & Economic Planning 2013).

2.2 Field data collection

The data used for the study is collected through field observation, related kinds of literature, and Landsat images of the study period. This period is selected because of its suitability to detect and distinguish, the forestland from other land cover classes in the study area. The images were selected based on availability, spatial resolution, and the overall

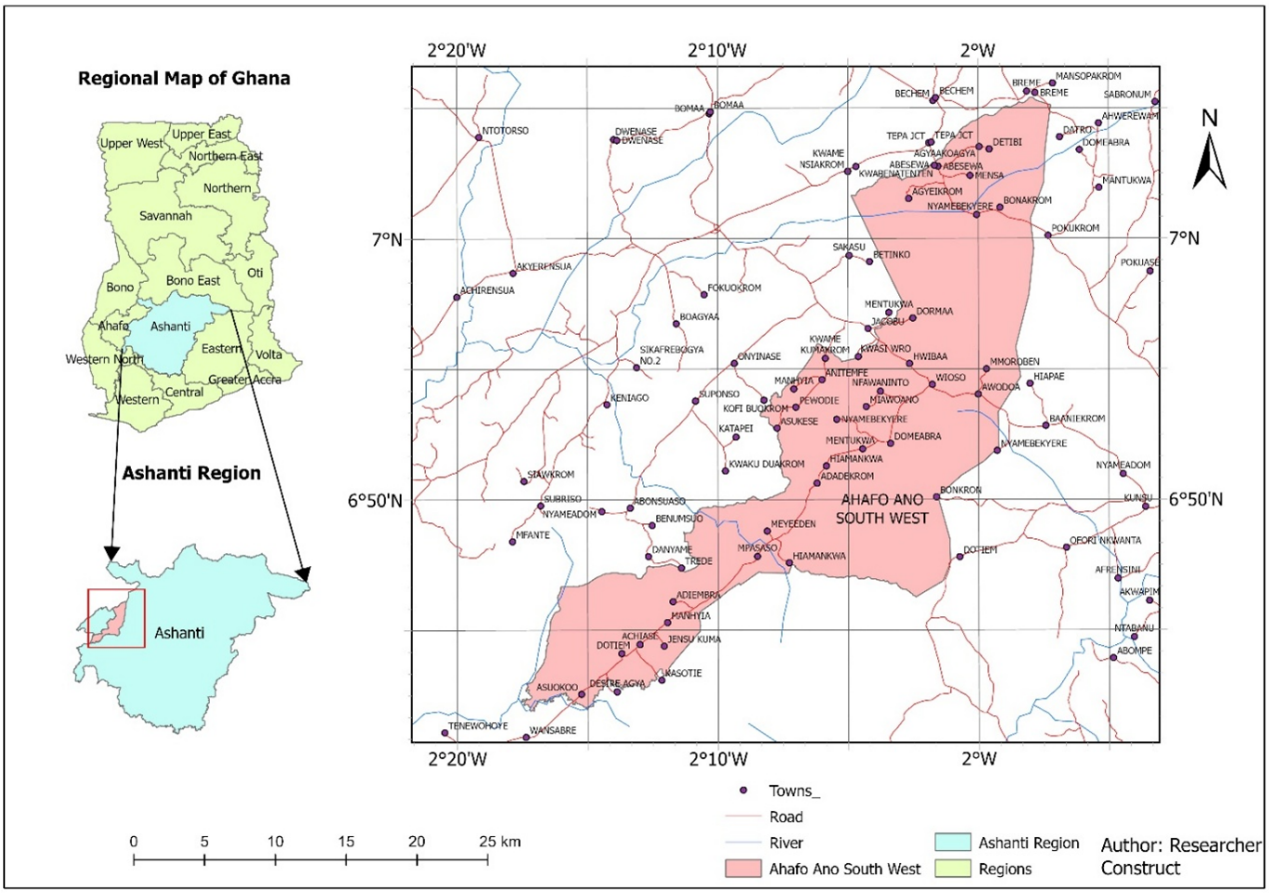

Fig. 1 A study area map indicating the Ahafo Ano South West District

quality of the images in terms of those with low cloud and scene cover (Duku et al. 2021). During the field data collection, Global Positioning System (GPS) essentials are used to collect point data in geographic coordinates from field surveys to record LULC feature coordinates within the study area. A total of 100 sample points are randomly selected, and they are detailed in Table 4. These sample points were used to validate the LULC classification and evaluate the precision of classified images (Thamaga et al. 2022).

2.3 Remote sensing data processing and analysis

Remote sensing satellite data (1994 Landsat 7TM, 2004 7TM, 2014 ETM+, and 2024 9 OLI_TIRS) provided by the United States Geological Survey (USGS) were attained and used to investigate the LULC, as well as change dynamics in the Ahafo Ano Southwest for 1994, 2004, 2014 and 2024. The images were resampled to a 30*30m spatial resolution and were taken in the same season and nearly free of clouds (Antwi-Agyei et al. 2019). All the processing (Table 1) and post-classification steps were completed using the software package QGIS 3.12.5. Before interpretation, image preprocessing including atmospheric and radiometric corrections was performed for each of the images (Baidoo & Obeng 2023). These corrections were performed to remove errors and improve the interoperability and quality of the remotely sensed image (Mushore et al. 2016). After image preprocessing, a supervised classification method with Maximum Likelihood Algorithms which examined the probability function of each class and assigned each pixel to the class with the highest likelihood (Tumelienė et al. 2021) was used to prepare LULC maps for the study.
Band combinations, visual interpretation, field data, and Google Earth were used to identify LULC classes in the Landsat images (Baidoo & Obeng 2023). Bands: 1 (coastal aerosol), 6 and 7 (thermal band), 9 (water vapor), 8 (panchromatic), 9 (SWIR – cirrus), 10 (LWIR-1), and 11 (LWIR-2) were excluded from the analysis, due to their spatial resolution (60 and 120 m) and their relevance relating to the detection of atmospheric features (Drusch et al. 2012). These have been considered to be inapplicable in vegetation monitoring (Immitzer et al. 2016). However, Blue, Green, Red, NIR, and SWIR 1 and 2 bands were used in this study. These bands are the very popular band combination used for vegetation analysis and vegetation studies and are useful for studying various stages of plant growth (Baidoo & Obeng 2023).
The images were geometrically corrected and projected to the Universal Transverse Mercator (UTM) zone 30N (Kankam et al. 2022). A shape file of the district was used to sub-set the area of interest from the satellite images. Using field observation, and previous related work of the research area and image classification, five land cover classes i.e., dense vegetation, sparse vegetation, built-up, bare lands, and wetlands were derived for the analyses of the study. Based on the principles of “complete consistency” and “temporal stability” (Hu & Hu 2019) sample points were filtered from the five land cover classes (Belay et al. 2022).

Table 1 Landsat data used for the study

Landsat Products	Acquisition date	Path/ Row	Spatial Resolution	Source
Landsat TM5	14/03/1994	194/055	30m	USGS
Landsat ETM+7	27/12/2004	194/055	30m	USGS
Landsat ETM+7	21/12/2014	194/055	30m	USGS
Landsat 9 OLI_TIRS	11/11/2024	194/055	30m	USGS

2.4 Change detection analysis and post-classification

This stage includes change detection and accuracy assessment techniques. A change detection technique was used to detect changes in LULC in the Owabi catchment (Peters 2019). Using ”-from, -to” information, a pixel-based comparison was employed to obtain change information on a pixel basis and to analyze the changes more quickly (Baffour-Ata et al. 2021). This method allows the determination of the difference between independently classified images from each of the years in question and it is the only approach in which “from” and “to” classes can be evaluated for each changed pixel (Baidoo & Obeng 2023). Cross-tabulation was used to compare classified image pairs from two separate decades of data to assess qualitative and quantitative features of the changes for the years 2004 to 2024. With the help of QGIS 3.12.2 software, a change matrix (Rawat et al. 2013) was created. Between 2004 and 2024, quantitative areal data on overall LULC changes, as well as gains and losses in each category, were compiled. Google Earth and GPS essentials during the field survey, were used to collect ground truth points to validate the accuracy of the classified images. Using a sample of 100 of the ground control points and from Google Earth imagery for each year, the study validated the classified images. This was achieved by calculating and analyzing the accuracy and Kappa statistics of each classified image (Jenness & Wynne 2005).

2.5 Classification accuracy assessment

The derived LULC change maps for the years 1994, 2004, 2014, and 2024 were assessed for classification accuracy assessment. The field data samples of 100 ground control points were used to validate the classified maps. An error matrix was used to assess the accuracy of the classification process (the overall, user, and producer accuracy) relative to the reference data. Further, the error matrix provided a comprehensive evaluation of the agreement, omission, and commission among the classification results and training data, with evidence on how the classification errors occurred (Pontius & Millones 2011). The accuracies of the classification are validated in Table 6 to show the kappa coefficients and the overall accuracies achieved. The kappa values for all the periods represent almost perfect reliability since they fall within 0.81 – 1 (Abass et al. 2018).

3 Results

3.1 Land use and land cover change development in the Ahafo Ano Southwest from 1994 to 2024

The Supervised Classification revealed LULC classes in 1994 (see Fig. 2) based on the spatial extent of the 1994 LULC map, with dense vegetation representing the most prominent LULC type in the Ahafo Ano Southwest with a land surface area of 32971.14 ha. The second dominant LULC type was spare vegetation, covering the land surface area of 16291.35 ha, representing 32.0% of the Ahafo Ano Southwest. Built-up occupied 191.97 ha, bare land 788.31 ha, and wetland accounted for 177.84 ha.

Based on the identified pixels, it was discovered that in 2004, the two most dominant LULC classes were dense vegetation showing land area of 34880.04 ha. During the previous year (i.e., 1994) it land area was recorded as 32971.14 ha, this shows a significant increase in this year. Sparse vegetation shows a decrease in land area in 2004 as it declined to 10 979.73 ha. Wetland area had increased to 355.68 ha whilst built-up and bare land had stood and increased at 199.08 ha, and 4006.08 ha in 2004.

2014 also shows a remarkable change in the LULC changes in the study area, where built-up was recorded at 363.51 ha, dense vegetation reduced to 24472.17 ha, spare vegetation recorded land area of 15597.09 ha, wetland stood at 55.71 ha whilst bare land increased to 9932.13 ha.

The assessment of Landsat 9 2024 satellite imagery indicated that spare vegetation and bare land areas have increased in the Ahafo Ano Southwest. Spare vegetation and bare land covered 24739.66 ha and 13690.98 ha of the land surface area respectively. This shows that the surface area of spare vegetation and bare land has increased from 1994, 2004, 2014, and 2024. After the classification, it was observed that dense vegetation and wetland lost their land surface areas to spare vegetation, built-up and bare lands. Dense vegetation reduced to 11502.18 ha, whilst wetland area has slightly reduced to 24.74 ha.

The spatial extent of LULC classes (ha) in the Ahafo Ano Southwest after the classification in Table 2.

Table 2 Areas of Land use and land cover classes

LULC Classes	1994 ha	2004 ha	2014 ha	2024 ha
Built up	191.97	199.08	363.51	463.05
Dense vegetation	32971.14	34880.04	24472.17	11502.18
Sparse vegetation	16291.35	10979.73	15597.09	24739.66
Wetland	177.84	355.68	55.71	24.74
Bare land	788.31	4006.08	9932.13	13690.98
Total Area	50420.61	50420.61	50420.61	50420.61

3.2 Land use and land cover spatial change pattern in the Ahafo Ano Southwest

The LULC maps and analyses show that certain changes in the study area have happened throughout the 30 years from 1994 to 2024. Table 2 above depicts the spatial extent of LULC proportions in 1994, 2002, 2014, and 2024, whereas Fig. 3 below depicts the graphical representation of LULC changes in 1994-2024. Over the 30-year study period, the majority of the LULC changes occurred in bare land, built-up, dense vegetation, and spare vegetation, whereas the wetland area had minor changes.

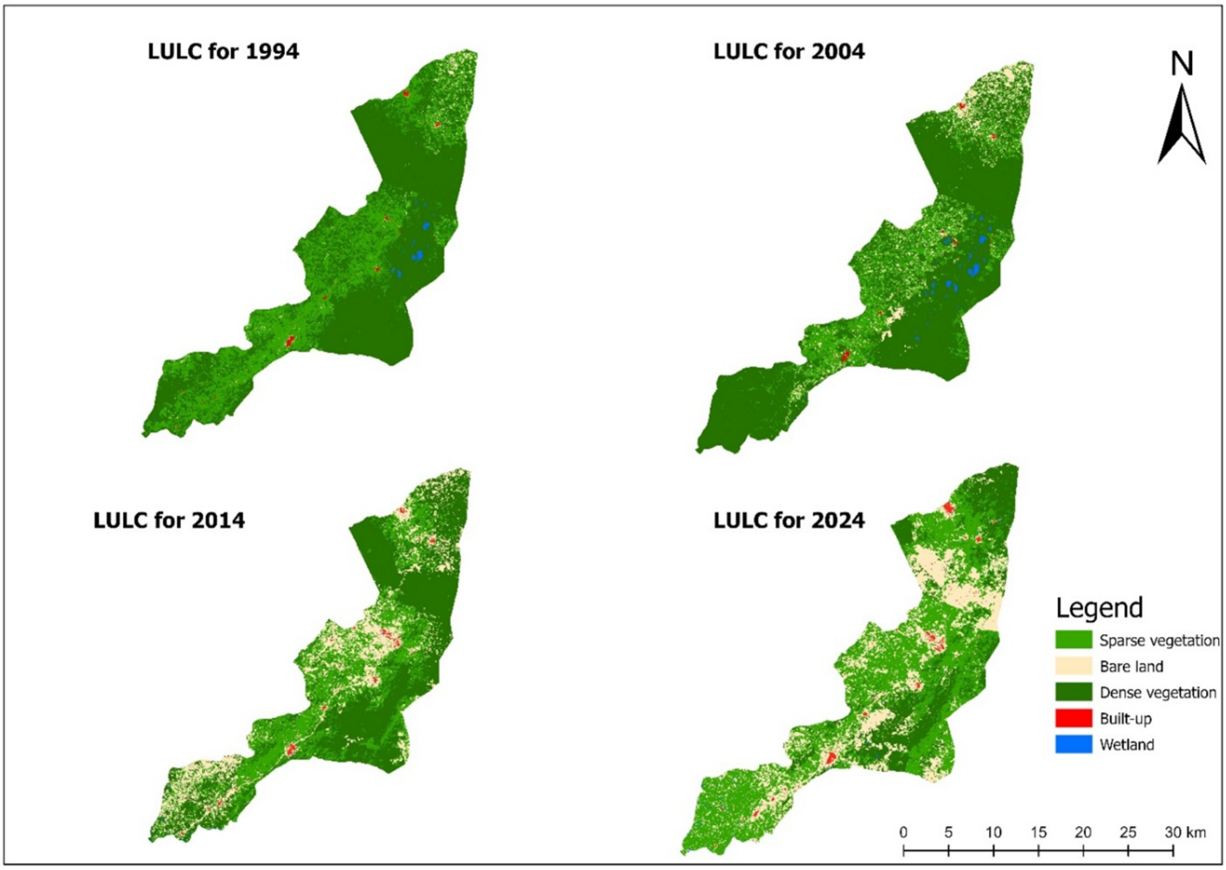

Fig. 2 Classified map of 1994, 2004, 2014, and 2024

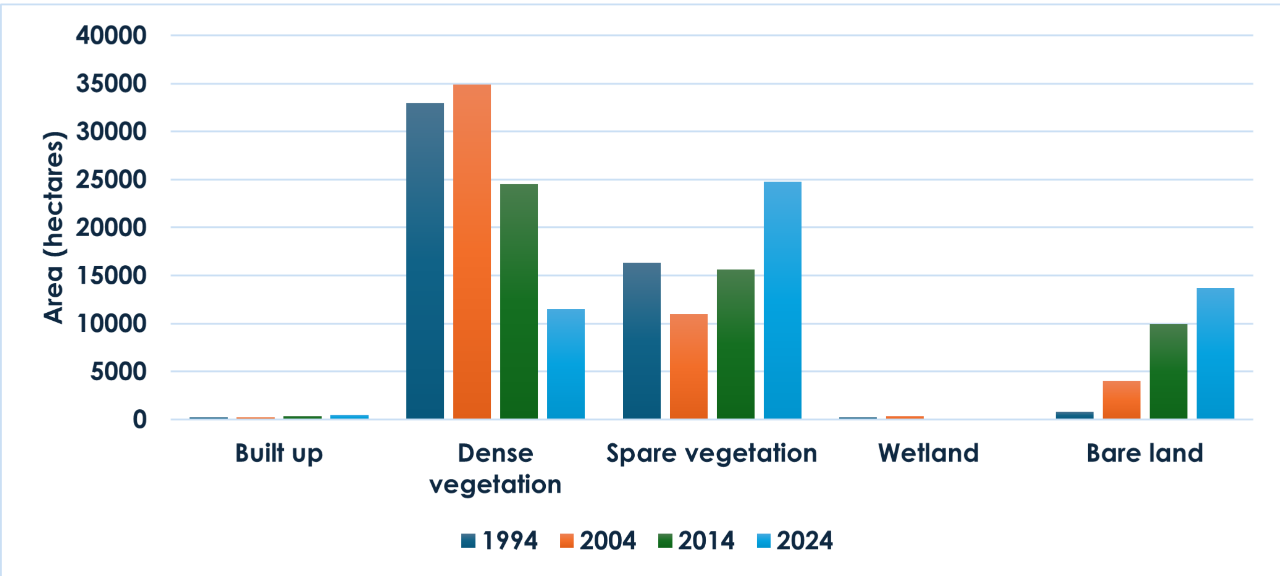

Fig. 3 Graphical representation of LULC classes for 1994-2024

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3.3 Land use and land cover change patterns in the Ahafo Ano Southwest

The Ahafo Ano Southwest LULC change trend analysis shows a shift in the size of the five LULC classes over 30 years. Following the classification, it was discovered that built-up areas had the greatest positive change, whereas dense vegetation had the greatest negative change. Between 1994-2004, land areas of built-up, bare land, dense vegetation and wetland experienced positive changes. From 2004 to 2014, land areas of dense vegetation and wetland decreased whilst built-up, bare land and sparse vegetation increased. Between 2014 and 2024, positive changes were seen in built-up, bare land and sparse vegetation whilst dense vegetation and wetland saw negative change. Built-up, bare land, and sparse vegetation saw a positive change in land area from 1994 to 2024, whereas dense vegetation and wetland saw a negative shift (Table 3, Fig. 4, Fig. 5).

3.4 LULC Classification accuracy

The overall classification accuracy, Kappa coefficient, and user and producer accuracies for different LULC classes for 1994, 2004, 2014, and 2024 were calculated and presented in Table 4 below. The LULC map of 2024 had an overall accuracy of 97.00% with a corresponding Kappa coefficient of 0.9576, whereas the LULC map for the years 1994, 2004, and 2014 had an overall accuracy of 96%, 98%, 95% with Kappa coefficients of 0.92, 0.97, and 0.92 respectively. These results are within the acceptable range, hence the study proceeded and used the classification output for the estimation of the forest ecosystems of the different LULC classes of the study area.

4 Discussion

The study has confirmed significant changes in land use and land cover (LULC) in the Ahafo Ano Southwest district in 1994 to 2024. Dense vegetation has reduced from 32971.14 ha to 11502.18 ha while sparse vegetation, built-up and bare land have increased to 24739.66 ha, 463.05 ha and 13690.98 ha respectively. The main underlying process associated with the land transformation is settlement expansion, which is mainly induced by population growth (Aitali et al. 2022). Settlement (built-up) has consistently increased in land coverage over the years despite being the smallest land use type. This was attributed to rapid urbanization taking place and human population growth as a result of the arrival of galamsey workers in the district (Anim-Gyampo et al. 2021). This is evidenced that the Ahafo Ano Southwest district is gradually becoming urbanized, as a result of the changes of the significance portion of it forest cover and increase in bult-up. Dense vegetation, which accounted for 32971.14 ha in 1994, has reduced to 11502.18 in 2024. The study results of the LULC change pattern between 1994-2024, had also shown positive changes observed in built-up, sparse vegetation and bare land whilst dense vegetation and wetlands experienced negative changes (see Table 3). According to studies, when population increases, and there is taste of housing constructions and farming activities, forest cover, i.e., dense vegetation is destroyed to give way for settlements and agricultural activities (Baidoo & Obeng 2023).

4.1 Comparison with Similar Studies

The results of the study has reviewed similar changes as the works of Tekle & Hedlund (2000) where there were a decrease in coverage by shrublands, riverine vegetation and forests, and an increase in remaining open areas, and settlements. Dembélé et al. (2024), saw an increased in croplands/mixed vegetation and non-vegetated in the Bobiri Forest region of Ghana, while closed forest consistently declined. This also conformed to findings received by Koranteng et al. (2023). Addo-Fordjour & Ankomah (2017), and Baffour-Ata et al. (2021) saw similar trend where closed canopy forest declined at the expense of open canopy forest in the Bobiri forest reserve. Similar results were seen by Obeng et al. (2023) in the dense river basin in Ghana where farmlands and forests have been converted into bare land and settlements. These studies attributed these changes to various underlying factors, such as a decline or inadequacy in forest conservation efforts, rapid socioeconomic developments, and institutional changes. This back to claim of Matsa & Muringaniza (2011) which attributable the cause to agricultural cultivation, mining and gold panning activities. This can also be attributed to increasing urbanization which has been pushing settlements back (Baidoo & Obeng 2023). Concerning the trend of urbanization and human population in the Ashanti region of Ghana, the expansion of population is likely to increase, hence, resulting in an increase demand for land for commercial, residential, and other infrastructure establishments (Duku et al. 2021). This is in support of study done elsewhere which agreed to declining

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Table 3 Land use and land cover change patterns between 1994 to 2024

LULC Classes	Change			
	ha	ha	ha	ha
Period	1994-2004	2004-2014	2014-2024	1994-2024
Built-up	7.11	164.43	99.54	271.08
Bare-land	3,217.77	5926.05	3758.85	12902.67
Dense vegetation	1920.06	-10407.87	-12969.99	-21468.96
Sparse vegetation	-5311.62	4617.36	9142.57	8448.31
Wetland	177.84	-299.97	-30.97	-153.10

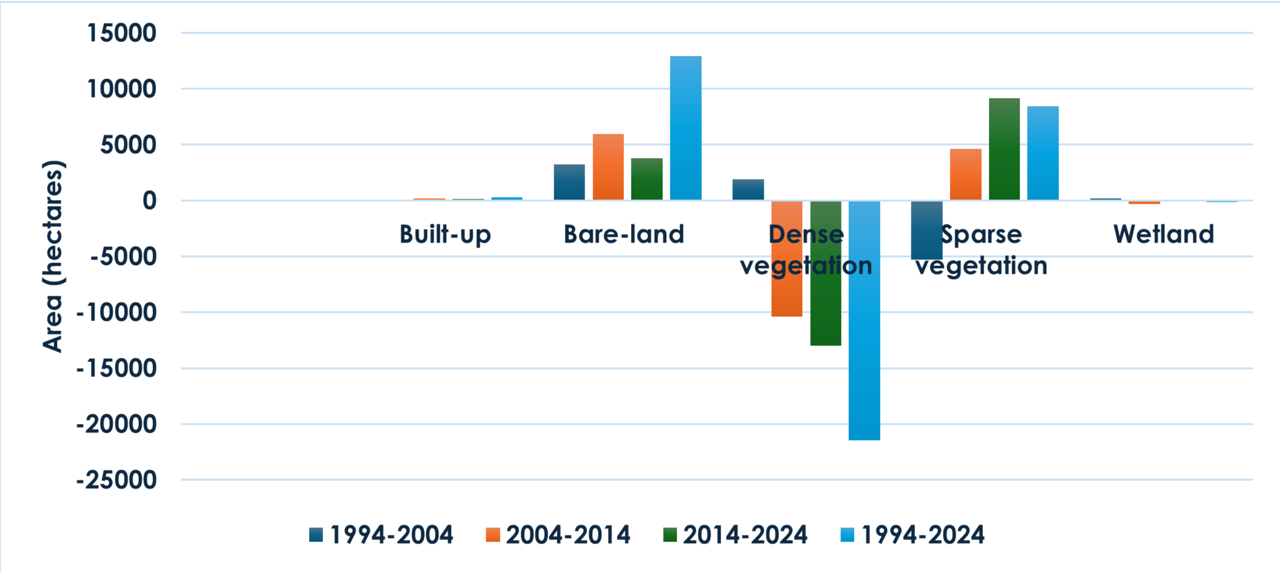

Fig. 4 Graphical representation of LULC change patterns (1994 to 2024)

Table 4 Accuracy Assessment for Classified Maps 1994, 2004, 2014 and 2024

Year	1994	2004	2014	2024
LULC class	PA UA	PA UA	PA AU	PA UA
Built-up	97% 93%	94% 98%	97% 99%	96% 98%
Dense Vegetation	98% 98%	99% 98%	96% 95%	99% 99%
Sparse Vegetation	93% 91%	95% 94%	97% 93%	98% 98%
Wetland	97% 98%	99% 99%	64% 80%	92% 97%
Bare land	79% 88%	97% 97%	97% 97%	92% 97%
Overall Accuracy	96%	98%	95%	97%
Kappa	0.92	0.97	0.92	0.95

PA: Producer Accuracy, AU: User Accuracy

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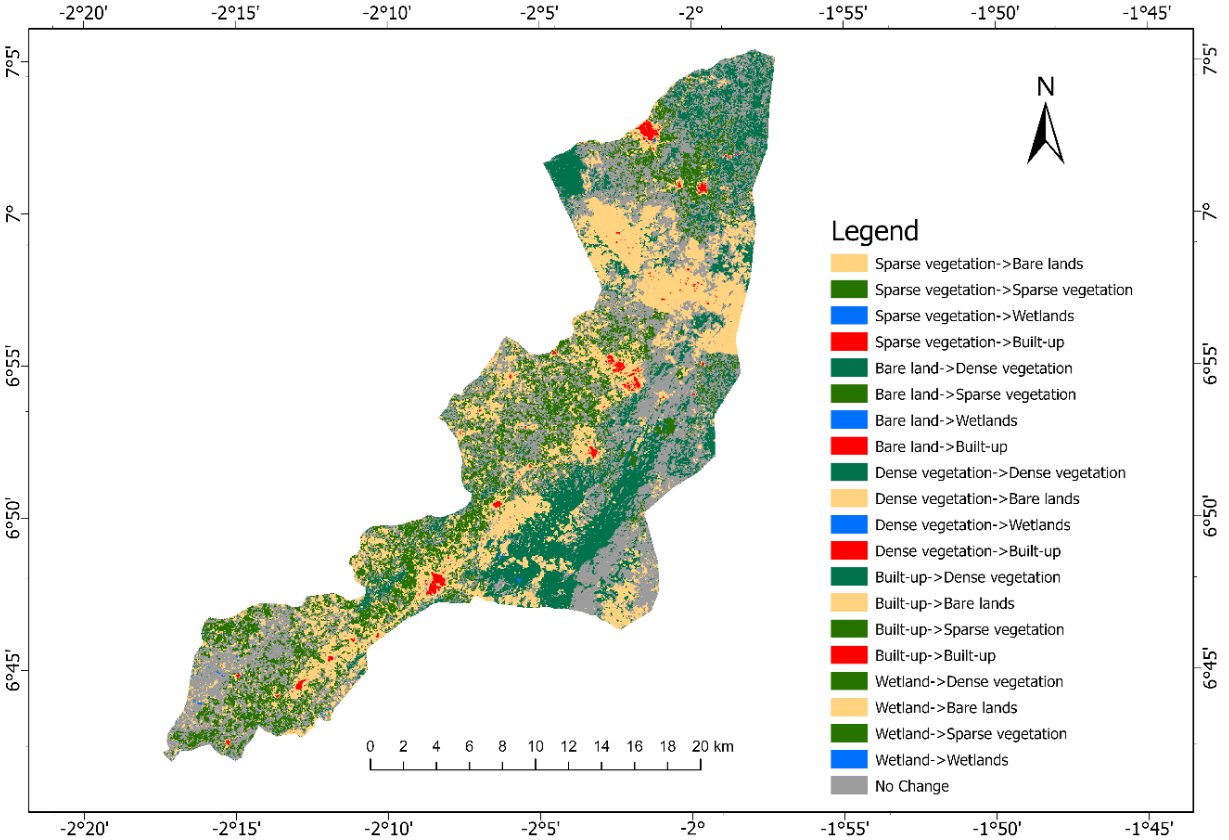

Fig. 5 Change Detection Map (1994-2024)

of dense vegetation and increase in built-up to population growth, commercial activities and porous land tenure systems (Kullo et al. 2021). Zeug & Eckert (2010) also characterized this to an increase in population, which led to the outward expansion of urban areas. A study conducted by Meshesha (2016) asserted that when population increases and there is an increased demand for food, additional lands will be required to fulfill food demand. Due to this, the result of the study saw an increase in spare vegetation (predominantly farmland) from 16291.35 ha in 1994 to 24639.66 ha (25.73%) in 2024. This is in agreement with reports found in the work of Bufebo & Elias (2021), where agricultural lands have expanded at the expense of forest land. In general, reductions in dense vegetation in the region 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 (Ampim et al. 2021). Nzunda et al. (2013) examined how socioeconomic factors affected changes in land use and vegetation cover in and around Tanzania's Kagoma Forest Reserve. The study findings demonstrate that the system of driving mechanisms of land use change is significantly influenced by overgrazing, shifting cultivation, the demand for forest products, agricultural development, rising crop prices, and a lack of land tenure. In sub-Saharan Africa, rural communities often rely heavily on natural resources for subsistence farming, fuelwood collection, and informal economic activities such as logging and mining. These socioeconomic practices, although essential for livelihood sustenance, frequently lead to unsustainable land use patterns that threaten forest resources and degrade the environment (Amagu & Akase 2025). This is of no exception in Ghana, where socioeconomic drivers of land-use change including urbanization, agricultural expansion (particularly for food crops and rubber), population growth, infrastructure development, uncontrolled mining (legal and illegal), and the oil and gas industry exacerbated by weak enforcement of land use laws, fluctuating agricultural commodity prices like cocoa, and the associated shifts in livelihood strategies and economic incentives (Iddrisu et al. 2023; Sarfo et al. 2022; Zhang et al. 2023; Darko et al. 2025). Demands for land usage have become conflicting due to the combined pressures of achieving economic advancement, accommodating growing populations, and the need to simultaneously exploit and conserve natural resources (Jamilah et al. 2025).

4.2 Drivers of LULC change

Concerning the driving forces, the LULC change are the consequence of combined effects of several elements, mostly due to the combined influence of natural and socioeconomic factors. This is because the relationship between LULC change and its drivers is complex and dynamic, since studies suggest that demographic changes any other any causal factors or drivers contributes mostly to land use changes (Bekere et al. 2023). However, a related literature by Gabisa et al. (2025) saw rapid population growth, inadequate land use planning and policy as the driving forces of these LULC changes. Liu et al. (2025), saw environmental forces such as climate, temperature, precipitation, slope, and digital elevation model; socioeconomic factors including economic development and population expansion as the driving forces of LULC changes. Abdeta et al. (2024) showed high population growth, agricultural land expansion, settlements, livestock grazing, and clearing of tree for woodfuel as drivers of LULC change. Climate change has resulted in increased intensity of extreme events such as heavy rainfalls subjecting tropical areas to floods (Babanawo et al. 2023). Adu et al. (2025), study results highlight a complex interplay of social drivers, especially population growth, agricultural expansion, urban development, and resource demands, in shaping LULC change in the Effutu Municipality in Ghana. Adarkwah et al. (2024) agreed on food crop production, rubber plantations, oil and gas establishments, and infrastructure development as the drivers of change. Other factors like institutional/political (governance structures, monitoring and enforcement mechanisms), technology (science and research, agroforestry, climate-smart agriculture, mining operations, transportation networks and technical efficiency), as well as cultural and behavioral (lifestyle, beliefs, traditions and perception) factors among these drivers of LULC changes (Sarfo et al. 2022). People's responses to economic opportunities, international commerce, and agro-climatic conditions, as well as institutional factors cause forest degradation (Nkonya et al. 2012). These factors of changes can of course leads to loss in carbon and probably to its emission into the atmosphere (Forest Commission 2023). Dense vegetation in the study area is expected to deplete since they come under pressure from settlement and agricultural land expansion (Addae & Oppelt 2019). The destruction of these ecologically important area does not only mean loss of habitat for many birds, turtles, and other creatures, but also would increase the incidence of flooding, water, and air pollution (Addae & Oppelt 2019). This is because rapid depletion of dense vegetation for infrastructure development, mining, and agricultural expansion alters local land cover and disrupts ecological balance, thereby influencing microclimatic conditions (Padhiary & Kumar 2025; Adu et al. 2025).

4.3 Policy, Management and Spatial Planning Implications

From the results, significant LULC changes (built-up, sparse vegetation, bare land, and dense vegetation have occurred in the study area due to various driving factors. The results identify settlement and agricultural expansions as the primary causes of land use changes in the district. Population growth appears to be the main driver of these changes, most notably the expansion of built-up and sparse vegetation at the expense of wetland and dense vegetation. This confirms the results of Oduro Appiah et al. (2021) reported in Tano-Offin forest reserve in Ghana where population growth and settlement expansion have resulted land loss of 1.9 and 1.4 times the amount of forest cover recorded between 1987 to 2017. The study results have shown expansion agricultural lands (sparse vegetation), built-up and bare land at the expense of dense vegetation. Based on this findings, the study conclude that the conversion from sparse vegetation to dense vegetation would be fully possible if there are plans to ensure that abandoned agricultural land is reserved specifically for forest recovery and not taken over by other land uses (Oduro Appiah et al. 2021). Also, It is therefore crucial for dense vegetation in the study area to be protected from agricultural and settlement expansion by enforcing strict encroachment regulations. Understanding the patterns and drivers of LULC change is necessary for rational and specific planning of sustainable land management (Arfasa et al. 2023; Kamwi et al. 2018). This is important because it enables the development of effective land management strategies, informs policy decisions to protect ecosystems and resources, supports sustainable development, helps predict future changes, and allows for better assessment of impacts on ecosystem services and climate change (Veldkamp & Lambin 2001; Msofe et al. 2019; Kristensen et al. 2016). This helps identify the specific causes of forest loss and degradation, allowing for the design of targeted interventions such as strengthened conservation policies, improved land-use planning, community-based livelihood development, and initiatives to build local capacity for sustainable forest management (Phompila et al. 2017; Precinoto et al. 2022; Addo-Fordjour & Ankomah 2017).

4.4 Future Research Directions

While this study provides valuable insights into long-term LULC dynamics in the Ahafo Ano Southwest District, several avenues for future research remain. First, higher-resolution satellite data (e.g., Sentinel-2 or commercial imagery) and advanced classification techniques such as machine learning could improve the detection of small or fragmented land cover types, including wetlands and secondary forest patches. Second, integrating socioeconomic datasets (e.g., census data, household surveys, land tenure records) with remote sensing analysis would allow a more comprehensive assessment of the drivers behind land-use change. Third, seasonal and interannual analyses are needed to capture short-term fluctuations in vegetation cover and the influence of extreme weather events, which are masked in long-interval snapshots. Future research should examine the ecological and social consequences of LULC change in more depth, including impacts on biodiversity, ecosystem services, carbon storage, and community livelihoods. Such interdisciplinary approaches would strengthen the scientific basis for designing sustainable land management and policy interventions in Ghana and comparable contexts across sub-Saharan Africa.

5 Conclusion

This study uses Landsat satellite data of 1994, 2004, 2014 and 2024 to investigate changes in LULC in the Ahafo Ano Southwest District. Analysis of the Landsat images shows substantial reduction of dense vegetation to sparse vegetation, built-up and bare land. Dense vegetation which stood at 32959.44 ha in 1994 in the Ahafo Ano Southwest district has reduced to 11502.18 ha in 2024. Similarly, the surface area of wetlands have reduced from 177.84 ha in 1994 to 24.74 ha in 2024. while built up (463.05 ha) sparse vegetation (24739.66 ha) and bare land (13690.98 ha) areas have increased steadily during the period. These changes can be linked to an increase in human activities (such as farming and mining) which is reflected in the population growth in the study area. The demand for land for farming and construction in different parts of the district due to the increasing population has resulted in the loss of dense vegetation and wetlands in the district. The study revealed expansion of built-up and increase in sparse vegetation (farmlands) as the primary causes of forest degradation in the study area. This is not far from findings of studies in other regions of the world where native forests have change to arable land as a results of agricultural expansion and human actions. One would agree that removing forest cover through LULC change has in some instances resulted in the scarcity or outright extinction of biodiversity. The main fear is that the Ahafo Ano Southwest could suffer a significant loss of vegetation cover if forests and wetlands continue to decline. This results is critical in determining and executing appropriate development policies that promote forest land expansion to boost vegetative cover and reduce the loss of ecosystems and carbon stock. This can be used by local and regional government agencies, developers, and policymakers to prevent forest degradation in the country.

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