Land Use Policy 142 (2024) 107184

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Agricultural land use policies and landscape dynamics: Evidence from rainforest agroecological zone

Wonder Kofi Adzigbli [a,b], Eric Duku [b,d,*], Gerald Atampugre [a], Christine Fürst [c], Benjamin Kofi Nyarko [a,**]

[a] Department of Geography and Regional Planning, University of Cape Coast, PMB, Cape Coast, Ghana
[b] Hen Mpoano (Our Coast), Takoradi, Ghana
[c] Martin Luther University Halle-Wittenberg, Institute for Geosciences and Geography, Department of Sustainable Landscape Development, Von-Seckendorff-Platz 4, Halle (Saale) 06120, Germany
[d] University of Technology Sydney, Faculty of Arts and Social Sciences, Climate, Society and Environment Research Centre (C-SERC), Sydney, Australia

ARTICLE INFO

Keywords:
Intensity analysis
Oil palm plantation
Land use/land cover change
Rain Forest Agroecological Zone
Rubber plantation, food security

ABSTRACT

Agricultural-land use policies play a crucial role in shaping agroecological landscapes globally. The evidence suggests that some of these policies tend to have undesired feedback/trade-offs, particularly about coastal resource use and conservation planning. The present study explores how agricultural policies influence land use/land cover (LULC) transition patterns in Ghana's Rain Forest Agroecological Zone (RFAZ). Landsat satellite images for 1991, 2008, and 2022 were acquired for the LULC mapping. Change detection and Intensity analysis were used to assess the pattern of land change. Also, documentary research processes were used to review and assess agricultural land use policies. The results showed that before rubber-related policy implementation, oil palm plantation was the dominant LULC type in the 1990 s. In the 1990 s and early 2000 s, there was a conscious government drive to leverage oil palm plantation development. This led to the growth in the size of oil palm plantations within the RFAZ landscape, considering the zone's conducive natural environment. However, between 2008 and 2022, corresponding to the period of the increased promotion of rubber cultivation through the Outgrower project in the RFAZ, rubber plantations became the predominant land use, with an area of 11,763.81 ha in 2008 and 21,611.61 ha in 2022. The results from the LULC mapping and the intensity analysis showed that the Rubber Outgrowers Plantation Project (ROPP) and Norpalm Smallholder Scheme Project (NSSP) have degraded the natural cover through rubber and oil palm cultivation. The authors conclude that landscape dynamics, particularly in rainforest agroecological zones, represent a nexus challenge transforming policy adaptation's discursive context. The study recommends that agriculture and landscape policy/projects must have/take intermediary steps to address the feedback/trade-offs from well-intended initiatives. The study further suggests that management plans and strategies in the RFAZ should be consistent with the strict protection of forest reserves and water bodies.

1. Introduction

Agricultural land use policies play a crucial role in shaping varying landscapes globally. These policies determine the allocation and utilisation of land for agriculture and agriculture-related production activities, like land clearing, planting, application of agrochemicals, harvesting, and transportation. The impact of these activities on the landscape could have consequences depending on the direction of the implemented agricultural land use policies. Globally, the shift from traditional agro-forestry systems to monoculture has been facilitated by favourable policies that contribute to large-scale commercial agriculture (Frison and IPES-Food, 2016). The ongoing need for food, industrial materials, and bioenergy production is changing natural ecosystems. This significantly impacts the composition and structure of landscapes (Pedroli et al., 2013). In recent times, the socio-economic drivers such as population growth, globalisation, and industrialisation, which are noted for this land transformation, have driven the direction of policies and interventions. Kociszewski (2018) argued that good policies increase

* Corresponding author at: Hen Mpoano (Our Coast), Takoradi, Ghana.
** Corresponding author.
E-mail addresses: ericduku23@gmail.com (E. Duku), bnyarko@ucc.edu.gh (B.K. Nyarko).

https://doi.org/10.1016/j.landusepol.2024.107184
Received 25 August 2023; Received in revised form 18 March 2024; Accepted 18 April 2024
Available online 4 May 2024

systematisation and economic development within the confine of their implementation.

The contribution of natural hazards such as climate change to land use/land cover (LULC) changes must be considered. For instance, the pattern of LULC change in any landscape, according to Gupta, Mathew, and Khandelwal (2020), results from the combined effect of natural and socio-economic factors and their use by humans in time and space. In the Rain Forest Agroecological Zone (RFAZ) landscape, climate change has been unveiled as an essential driver of landscape transformation (Tasser et al., 2017). Acknowledging the above, countries, particularly those in the global south, have adopted several policy initiatives and international agreements to mitigate and adapt to the changing milieu of climate and global environmental change (Fletcher and Reed, 2022; Khan and Roberts, 2013). Some policy initiatives are related to agricultural production and land use planning. However, there is evidence that some agricultural land-use-related policies tend to have undesired feedback (Christiaensen et al., 2020) on the landscape. Thus, policy feedback results in massive cash crop cultivation among local communities to feed local industries.

According to the Food and Agriculture Organization (FAO) (2023), the global agricultural landscape provides employment opportunities to about 884 million (27%) people worldwide, which contributes 4% to the world's gross domestic product (GDP). In sub-Saharan Africa (SSA), agriculture, on average, accounts for 15% of the GDP (OECD/FAO, 2016). Aside from employing the growing population in urban and rural communities, the forest agroecological landscapes have a high aesthetic, cultural, and ecological significance in society (Sahle and Saito, 2021). The natural vegetation and wetlands that provide various ecosystem services necessary for the livelihood and general well-being of households relying on forest resources are being destroyed by the unstainable exploitation of the forest landscape (Duku et al., 2022).

The RFAZ landscape of Ghana has been primarily dominated by subsistence farming, driven by rubber and oil palm production (Asante-Yeboah et al., 2022). Since the pre-colonial period, agricultural activities have been supported by structural adjustment, labour, and market policies, resulting in agrarian commercialisation (Yaro et al., 2018). These policies asserted the process and relationships between people and capital in the quest to understand the trajectories and outcomes of current commercialisation models. Aside from food production, the agriculture sector has been a significant provider of raw materials (for instance, rubber and oil palm) for industries and the international market through export (Asuming-Brempong, 2013). Drawing from these policies, private investors have initiated agricultural projects known as the Rubber Outgrowers Plantation Project (ROPP) and the Norpalm Smallholder Scheme Project (NSSP), which financially support the cultivation of rubber and oil palms among local communities. The ROPP and NSSP promote industrial crops, mainly rubber and oil palm. The rapid conversion of natural vegetation, wetlands, and croplands to rubber plantations by smallholder farmers within the RFAZ landscape may affect food crop production and hinder biodiversity protection. Recent studies within the landscape have explored the potential supply of provisioning and regulating ecosystem services (Asante-Yeboah et al., 2022) and cultural ecosystem services (Kankam et al., 2021). This clearly shows that there is limited knowledge of the interplay between agricultural land use policies and the changes in the landscape. Analysis of the LULC change in response to the implemented agricultural land use-related interventions such as ROPP and NSSP in an agrarian landscape like the Ahanta West Municipality will provide vital information concerning the trade-off in land use decision-making among farmers. This information will guide development and physical planners in making informed decisions towards achieving socio-ecological sustainability. Against this backdrop, the current study examined the landscape dynamics in the RFAZ of Ghana in response to agricultural land use policies promoted by the government to sustain economic transition and environmental integrity.

The study provides relevant information that will improve the knowledge and understanding of the nexus of policies and landscape dynamics in an agricultural-driven landscape, particularly in Africa (Milder et al., 2014; Tanui, 2015). Understanding the interplay of policies and landscape changes would spearhead the agenda of landscape sustainability as scientists would specifically enlighten government authorities on policies that must be implemented to conserve the agricultural landscape.

2. Materials and methods

2.1. Study area description

The study focused on the Ahanta West landscape in the Western Region of Ghana between longitude 1° 58' W and latitude 4°45' N. The landscape falls within the Rainforest Agroecological Rone within the Upper Guinean Forest Ecosystem of West Africa (Fig. 1). The landscape has an estimated area cover of approximately 591 km^2 (GSS, 2014). The landscape falls within Ghana's southwestern equatorial climatic zone, which experiences the highest mean temperature of 34°C between March and April. The lowest mean temperature in the landscape is 20°C, which was recorded in August. The landscape experienced a double maxima rainfall of over 1700 mm with very high relative humidity (75%–85%) in the rainy season and low relative humidity (70%–80%) in the dry season (GSS, 2014). The landscape is bounded to the East by the Shama Ahanta District, to the West by the Nzema East District, to the North by Mophor Wassa East and Wassa West, and to the South by the Gulf of Guinea. The recent discovery of oil and gas within the landscape at Cape Three Points has resulted in the emergence of several oil drilling companies, residential development, and agricultural land uses (Boohene and Peprah, 2011). This development has translated to losing croplands and forests to build-up areas. The initiation of agricultural programs has also manifested in the loss of ecological lands to rubber and oil palm plantations in the landscape. Expanding rubber and oil palm plantations into ecologically sensitive areas in the landscape threatens biodiversity conservation and ecosystem integrity, causing habitat fragmentation. The population in the landscape has increased over the years and is raising the cash crop farmers' population farming. The economic development in the landscape is primarily driven by cash crop farming, resulting in the capture of several hectares of rubber and oil palm plantations.

2.2. Study schematics

The methodology proceeded in two parts: geospatial analysis and policy review, as displayed in Fig. 2. The first part consists of geospatial analysis, which deals with satellite image acquisition, image processing, georeferencing, radiometric calibration, supervised classification, transition matrix, accuracy assessment, and intensity analysis. The second part involved a policy review. The policies reviewed were the Structural Adjustment Program (SAP), Rubber Outgrowers Plantation Project (ROPP), Norpalm Smallholder Scheme Project (NSSP), Food and Agriculture Sector Development Policy (FASDEP I), Food and Agriculture Sector Development Policy (FASDEP II), and Ghana National Spatial Development Framework (GNSDF).

2.3. Data and sources

2.3.1. Remote sensing data

Landsat satellite images from 1991 to 2022 were downloaded from the United States Geological Survey's website (http://earthexplorer.usgs.gov/). The study used three segment years images (i.e., 1991, 2008, and 2022) for the spatial analysis (Table 1). The downloaded satellite images for the years 1991, 2008, and 2022 were Landsat-4 Thematic Mapper (TM), Landsat-7 Thematic Mapper (TM), and Landsat-8 Operational Land Imager (OLI)and Thermal Infrared Sensor (TIRS), respectively. The Landsat 4-TM consist of seven bands with a

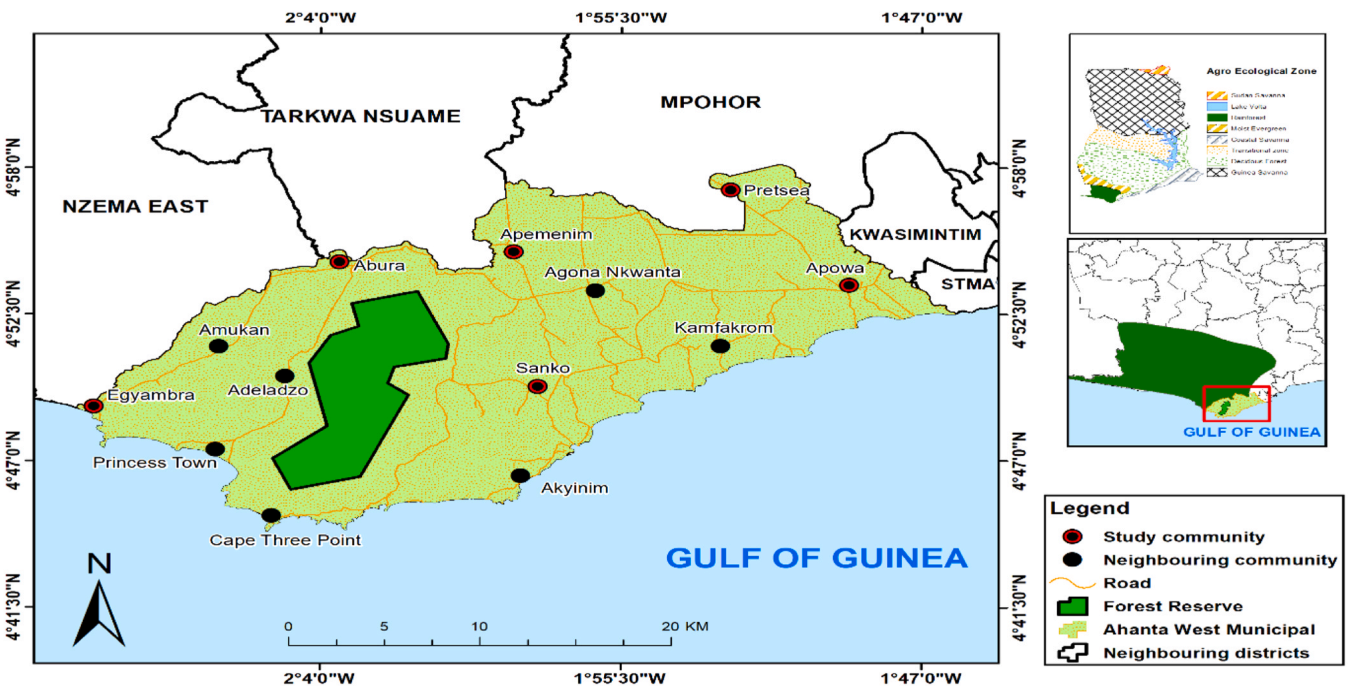

Fig. 1. Map of Ahanta West Municipality in the Rain Forest Agroecological Zone of Ghana.

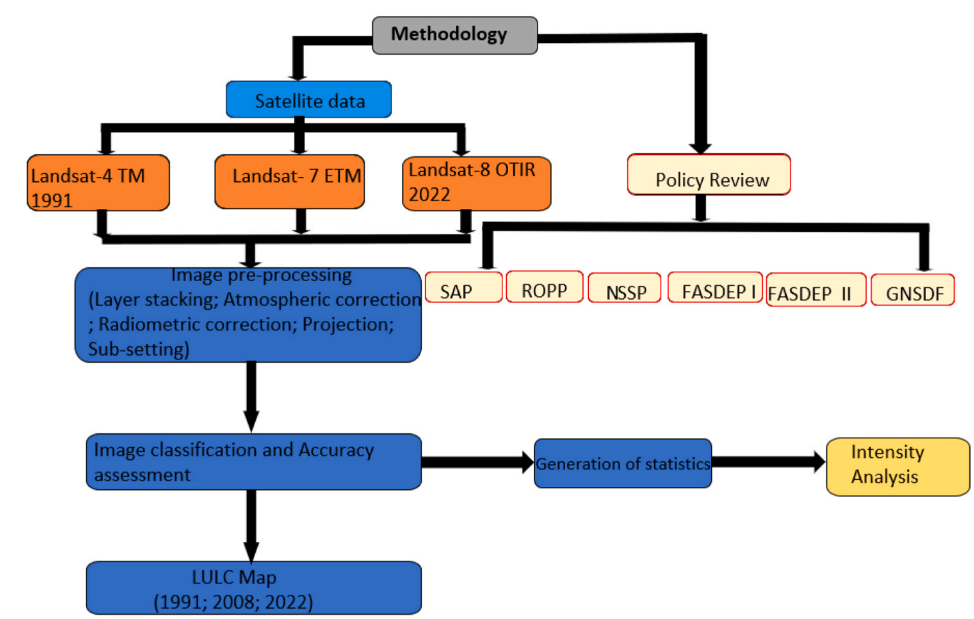

Fig. 2. Methodological flowchart of LULC changes, intensity analysis, and policy review.

Table 1
Description of downloaded Landsat Satellite data.

Sensor platform	Year of Acquisition	Path/ Row	Spatial resolution (m)	Spectral band
Landsat-4 TM	01/01/1991	194/ 057	30	1,2,3, 4
Landsat7 ETM	01/02/2008	194/ 057	30	1,2,3, 4
Landsat-8OLI_TIRS	03/03/2022	194/ 057	30	2,3,4,5

Source: Downloaded satellite image metadata

spatial resolution of 30 m for bands 1–5 and 7. The Landsat7 TM images consist of eight spectral bands with a spatial resolution of 30 m for Bands 1–7. Landsat-8OLI_TIRS images consist of nine spectral bands with a spatial resolution of 30 m for Bands 1–7 and 9. The study used bands 1–4 (Blue, Green, Red, and Near Infrared) for Landsat-4 TM and Landsat7 ETM. For the LULC map 2022, the study uses the multispectral bands (Blue, Green, Red, and Near Infrared) of Landsat-8 OLI_TIRS (Blue, Green, Red, and Near Infrared). The availability of the image, the amount of cloud and scene cover, and the overall quality influenced the satellite image selection. The selected images help to assess the land cover of the Rain Forest Agroecological zone from 1991 to the present. The table below shows the satellite image properties and spectral bands for the Rain Forest Agroecological zone.

2.3.2. Field data

The study adopted a participatory mapping approach that engaged food and cash crop farmers and some key community leaders (with at least 30 years of stay in the community) to collect spatial and non-spatial data on the major LULC types characterising the RFAZ landscape (Duku et al., 2021). The spatial data was in the form of geographic coordinates collected with the help of Garmin GPSMAP 62 21E001502 (Model 01102381, Taiwan). These geographic coordinates were used as the ground control points (GCPs) for the LULC classification and accuracy assessment. The non-spatial data was in-depth interviews. The in-depth interviews were conducted with various community leaders using an interview guide to confirm the different LULC types before and after the implementation of the agricultural land use policies.

2.4. Satellite image processing and analysis

2.4.1. Satellite image processing and classification

The satellite image pre-processing creates room for correcting recorded pixel values and establishing a substantial link between the acquired image data and the biophysical process. All the Landsat satellite images for the three-segment years were first projected into the Ghana Metre Grid Coordinate System. This was meant to ensure consistency and accurate assessment of the landscape. The Landsat-7 ETM, which had scanlines, was corrected with the Landsat gap fill, an extension tool in Environment for Visualizing Images (ENVI) version 5.3 software. Atmospheric correction was performed on the imageries using *ENVI* version *5*.3. The Landsat scenes in each segment year were mosaic, and the study area was subsets *from* the mosaic scenes. A Support Vector Machine-supervised classification was then applied to the pre-processed images (Jaya et al., 2022; Viana et al., 2019). In addition, various band combinations were carried out, and visual interpretation was done using shape and texture. This initial analysis, together with the GCPs from the field and on-screen digitisation, helped to arrive at the final signature file of eight (8) major LULC categories: wetland, waterbodies, shrubland, *f*orest, *o*il palm plantation, built-up (including all kinds of building and concrete surfaces), croplands and rubber plantation. The LULC was developed based on exp*e*rt knowledge from the study area. The LULC class statistics were generated in ArcGIS Pro in hectares. The percentage of each LULC category was then calculated in Microsoft Excel version 16 by dividing the area of each LULC category by the total land area, which is then multiplied by a hundred (100). Table 3 presents a description of LULC categories in the study area. The classification scheme of the study area was designed based on the researcher's prior knowledge of the existing features of the landscape (Alshari and Gawali, 2021). The in-depth interview with the community leaders helped map eight LULC categories, as indicated in Table 2.

2.4.2. Accuracy assessment

The accuracy assessment of the generated LULC maps was carried out using samples from the field data. The validation dataset was used to check the accuracies of the three classified satellite images. The accuracy assessment generated overall accuracy, kappa statistics, and producer and user accuracies based on the confusion matrix.

Table 2
LULC Categories and their Description.

LULU Categories	Description
Wetland	Wetland and mangroves
Waterbodies	Rivers
Shrublands	Short woody vegetation, including both open areas, bushes, and fallow lands
Forest	Cape Three-point Forest reverse and thickets
Oil Palm	Oil palm farms (smallholder and large scale -plantations as well as coconuts.
Built-up	Residential, industrial, and rural communities. It includes all kinds of buildings and concrete surfaces, such as roads.
Croplands	Annual and biannual food crop farms
Rubber	Establishes plantations and outgrower smallholder plantations

The LULC maps for 1991, 2008, and 2022 were developed after the image classification in the landscape.

2.4.3. Change detection

This study used the post-classification change detection method to analyse the land transition and identify LULC categories that duly contributed to landscape transformation over the two-time intervals for the study. Change detection is the most common approach often used in landscape monitoring and assessment, even though the approach is considered time-consuming and sensitive to the combined errors in the two time periods (Zhou et al., 2014). It also helps analyse the spatial extent and distribution of land features in the landscape (Mallupattu and Sreenivasula Reddy, 2013). The change detection approach fits into this study because of its capacity to reduce the impact of the sensor, atmosphere, and environment on the output transition matrix (Tewkesbury et al., 2015). The transition matrix indicates the areas changed in converting one LULC category from the initial year to the end of the final year for the two time periods used, reflecting policy dynamics. The values indicate the persistence in the diagonal of the transition matrix. The off-diagonal values showed the transitions in the LULC categories across the two time periods. The transition matrix also summarises the gross gain, gross losses, and net change, which helps to understand the nature of the transition in the study landscape (Aldwaik and Pontius, 2012). The landscape achieves a gross gain when all the individual LULC categories in the previous year shift from other land cover types in the subsequent year. Gross losses are the sum of all land cover types that have changed from the previous year to different land cover types in the subsequent year, while net change is the difference between gross gains and gross losses.

2.5. Intensity analysis

The intensity analysis is a mathematical framework developed by two researchers, Safaa Zakriah Aldwaik and Robert Gilmore Pontius Jr., to examine variation within various sets of LULC over some time (Ekumah et al., 2020). This involved analysing the number of temporal changes that occur in a particular landscape by comparing it to the total area. The intensity analysis operates on a three-level scale: interval, category, and transitional (Aldwaik and Pontius, 2012). The interval level analysis calculates the variation rate and changes in land sizes across various time intervals. It also helps to understand the annual rate of change in the landscape. The category-level analysis analyses changes within the LULC categories across the landscape. Lastly, the transitional level analysis concentrates on the variations in land sizes and intensity in gaining and comparing LULC categories in each time interval (Zhou et al., 2014). It considers how a category gains from other LULC categories during each time interval. The intensity analysis generates a uniform line across all three level scales. The uniform line is a hypothetical straight line on a graph where the intensity of LULC remains constant or uniform across the periods. The uniform line can help identify patterns or trends over the period by comparing the uniform line to the three levels (interval, categories, and transitional) intensity. Concerning interval level analysis, when the uniform line is compared, it helps to determine the fast or slow annual rate of change within the time interval. The estimated area could be active (when the intensity is above the uniform line) or dormant (when the intensity is below the uniform line) under the category-level analysis. Similarly, under the transitional level of intensity, a LULC category is known as a target if a gaining or losing LULC category exceeds the uniform line. If the gaining or losing category does not reach the uniform intensity line, it is termed an avoided category. The study adopted a mathematical framework developed as a Microsoft Excel program by Safaa Zakaria Aldwaik and Robert Gilmore Pontius Jr. (https://sites.google.com/site/intensity analysis/ (accessed on 22 February 2021). The framework simplified in a Microsoft Excel program uncovers differences within categories across varying time intervals by comparing uniform intensity to observed intensities of temporal changes among categories (Zhou et al., 2014). The quantities from the transition matrix served as input data for the intensity analysis conducted at three levels: interval, category, and transition (Akinyemi and Mashame, 2018; Ekumah et al., 2020).

2.6. Policy review

The study employed a documentary review approach and set indicators for the policy review. These policies include the Rubber Outgrowers Plantation Project (ROPP), Norpalm Smallholder Scheme Project (NSSP), Ghana National Spatial Development Framework (GNSDF), National Environmental Policy (NEP), Structural Adjustment Program (SAP), Food and Agriculture Sector Development Policy (FASDEP I), and Food and Agriculture Sector Development Policy (FASDEP II). These policies were purposely selected for review due to their immense contribution to landscape dynamics in the study area. The policy-adopted indicators are categorised into three main themes: production, conservation, and livelihoods. The production theme focuses on sustainable production, landscape management, and production systems. The conservation theme was categorised in the policies based on biodiversity conservation, watershed protection, and ecosystem services. The livelihood theme focused on well-being, infrastructure, and human settlement as indicators for assessing the livelihood dimension of agricultural land use policies.

3. Results

3.1. Policies in landscape dynamics

The Structural Adjustment Programme (SAP 1983–1990) is an economic recovery program launched in Ghana under the World Bank and the International Monetary Fund. The purpose of the SAP was to reverse economic decline via resource mobilisation, market liberalisation, and public sector and institutional changes. The SAP was adopted to fix socio-economic problems such as increasing debts, declining foreign exchange reserves, and unemployment. The policy direction of SAP was to encourage foreign investment and eliminate price controls and subsidies. The reason for removing price controls and subsidies was to encourage growing productivity, especially in agriculture. The core pillar of the SAP was to resolve supply-demand imbalances in the agricultural industry by incentivising producers to maximise output. The SAP creates room for improvement in agricultural productivity while minimising risk and uncertainties. The strategies adopted under the SAP in managing agriculture production uncertainties include sensitisation of post-harvest activities, strengthening production incentives, and providing infrastructure. One primary policy objective of the SAP relating to agriculture was to restore production incentives and renovate infrastructure to improve conditions for agriculture production. Even though the SAP also focused on reducing state-owned sectors and businesses by privatising state-owned enterprises, the Government of Ghana entered into a financing agreement with the then Caisse Française de Development (CFD), now Agence Française de Development to rehabilitate and manage the company's rubber plantation and to build a new rubber processing plant at Apimenim. After the rehabilitation in 1996, the French management company Societe Internationale d Plantation d' Hevea (SIPH) became the company's major shareholder. The reduction in government enterprises and businesses led to a reduction in public-sector employment. The documentary review of SAP indicated that SAP heavily targeted the production indicator but failed to consider conservation. The excessive production might have contributed to the general well-being of farmers. Since the government provides subsidies to farmers to encourage growing productivity, especially in agriculture, farmers are likely to make more income to improve their loverhood. Again, the government could also generate more revenue to reinvest in infrastructure development.

The Ghana Rubber Estate Company Limited (GREL) was wholly owned by the government of Ghana when Firestone sold its shares. The government initiated the Rubber Outgrower Plantation Project (ROPP) in 1995 to promote economic empowerment and the development of rubber farming in the RFAEZ. The objective of the ROPP was to develop rubber as an industrial crop in Ghana while at the same time promoting best farming practices in rubber farming. It also helps farmers develop clonal rubber plantations. GREL coordinates the ROPP with the Agricultural Development Bank (ADB) and National Development Bank (NIB). The ROPP was also financed by international organisations such as Agence Française de Développement and the World Bank, which uses a contract farming scheme. The scheme has a tripartite structure that involves GREL as the buyer and the Rubber Outgrowers Agents Association, with financial support from ADB as producers. The ADB provides long-term loans to smallholder farmers to cultivate and rehabilitate rubber plantations. Smallholder farmers must deliver the latex rubber to GREL to pay for the planting materials under the tripartite contract (Ewusi Koomson et al., 2022). The purpose of the development of rubber was to help improve farmers' income and alleviate poverty in rural areas (Paglietti and Sabrie, 2012). ROPP intends to provide high-quality extension services to rubber out-growers using advanced and innovative technologies in rubber plantation farming across the ecological zone. The project was undertaken in phases to help implement sustainable cultivation strategies in rubber production. The project's first phase lasted from 1995 to 1999, while the second phase was launched in 2000. The project spearheaded the cultivation of rubber plantations, thus increasing the hectares of rubber plantations over the period. According to Ewusi Koomson et al., (2022), 400 outgrow planters over 1200 ha of rubber plantation from 1995 to 1999 contributed to changes in the agricultural landscape. Though the project policies targeted the economic independence of cash crop farmers in the RFAEZ, agrarian landscapes are susceptible to human influences and disturbances. The financial support from these donors has encouraged more farmers to enter rubber plantations, expanding rubber plantation cover to dominate the landscape.

Norpalm Smallholder Scheme Project (NSSP) was implemented in 1996 as a smallholder plan that covered about 2471 acres of land. The NSSP aimed to guarantee a constant supply of oil palm bunches at a lower operational cost to the business. It also focuses on providing a livelihood to smallholder farmers. The scheme piloted about 278 acres of land with 40 smallholder farmers from four (4) major oil palm growing communities. These communities include Ewusiejoe, Mpohor, Ahanta Yabiw, and Bokoro. The program was open to all residents of these communities except for natives who worked for the Norpalm oil company. The company gave the smallholders a loan over five years as part of their agreement with the corporation to develop 6 acres of land for each farmer. The essential requirement for participation in the scheme was accessibility to land. The scheme provided access to labour, crop seeds, oil palm seedlings, equipment, and agrochemicals such as herbicides, fertilisers, and insecticides as part of the contract with smallholder farmers. The scheme also facilitates the transportation of harvested oil palm bunches from the farms to the Norpalm processing mill. The NSSP operates based on providing financial support to smallholder farmers through a loan facility consisting of monetary and non-monetary components. The principal's payment and the loan's interest were made flexible by deducting them from what the smallholders earned from selling their oil palm bunches to the company over five years. The deduction was different from one farmer to another. This was based on the sort of inputs used, the farming techniques used, and the overall volume of palm fruits collected. For instance, fertiliser costs are subtracted over a year, while weeding costs are subtracted over four months. The smallholders would own the farm for 25 years, the length of an oil palm tree's economic life. The Norpalm oil company follows the World Bank-established pricing structure, whereby oil palm bunches are purchased for about 10% of the global market price of crude palm oil.

This indicates that the price for the oil palm bunches has no bearing on the smallholders.

Food and Agriculture Sector Development Policy (FASDEP I 2002–2007) was published in 2002 by Ghana's Ministry of Food and Agriculture (MoFA), and it was the country's first comprehensive strategy. The policy was issued based on the 1996 Accelerated Agriculture Growth and Development Strategy. This program aimed to boost the private sector as a growth engine. FASDEP I focused on creating a framework for agricultural modernisation and using it as a springboard for rural economic change. However, the Poverty and Social Impact Analysis indicated that FASDEP I needed help accomplishing the expected goals due to several substantial shortcomings. FASDEP I has seven pillars in its examination. These pillars include human resource development, technological development and distribution, infrastructure development, market promotion of certain commodities, greater access to financial services, crosscutting concerns, and implementation framework. The failure in FASDEP I could be attributed to limited access to financing and technology, inadequate infrastructure, and restricted access to input and product markets. Also, poor coordination between MoFA and Metropolitan, Municipal, and District Assemblies (MMDAs) has crippled FASDEP I. Thus, the roles and engagement between these institutions needed to be defined appropriately (MoFA, 2007). These failures prompted the government to review FASDEP I to implement FASDEP II.

The FASDEP II was created in 2007 as a long-term government policy goal for the agricultural sector's growth. The objective of the FASDEP II policy was to provide farmers with improved planting material and practices, extension services, and access to credit. The aim was to help farmers expand the average farm size per holder. Thus, this creates a conducive environment to facilitate private sector investments in commercial crop production chain, infrastructure improvement, and subsidies for agriculture inputs such as improved seedlings, fertilisers, and pesticides. The growth in the sector was envisaged to ensure industry players are well-positioned to take advantage of the sector's expanding potential. The FASDEP II policy considered increased growth in incomes within the agricultural sphere. This policy seeks to employ diversification into cash crops while addressing farmers' access to resources by forming farmer groups and farmer-based organisations. Furthermore, the policy advocates for infrastructure development and private sector involvement regarding agriculture investments. Another policy focus of the FASDEP II was to increase competitiveness and enhance integration into domestic and international markets. FASDEP II policy aims to take advantage of supporting production levels to meet both domestic and international market demand. Further, the policy seeks to increase the capacity of smallholders to improve the quality of agriculture produced to meet the international standard. The FASDEP II helps expand domestic markets through good agricultural practices that meet sanitary and phytosanitary requirements for export. Moreover, other sub-sector policies have been developed under the FASDEP II to assist in achieving the policy's overall goal.

The Ghana National Spatial Development Framework (GNSDF 2015–2035) is a long-term spatial development plan from 2015 to 2035 to accelerate spatial development in Ghana. The GNSDF was created in collaboration with the Ministry of Lands and Natural Resources (MLNR), the Ministry of Environment, Science, Technology, and Innovation (MESTI), the Land-use and Spatial Planning Authority (LUSPA), and the National Development Planning Commission (NDPC). The GNSDF was developed with input from the first Medium-Term National Development Policy Frameworks and Ghana Share Growth and Development Agenda (GSGDA) I and II. It also cushions inputs from sectoral plans and policies in the economy, transportation, education, health, environment, energy, climate change, and land use. The policy also relied on inputs from several national, regional, and district government agencies. The framework is anticipated to contribute to Ghana's national long-term development strategy by assisting local governments in preparing regional, subregional, and district spatial development frameworks and lower-level plans. GNSDF has five primary goals. The first goal was to balance polycentric growth and development. The GNSDF is concerned about improving regional, national, and international connectivity. The policy also looked forward to strengthening metropolitan cities and promoting the development of networks and secondary cities. Finally, the GNSDF ensures long-term development and the preservation of natural resources. The policy assists in preventing settlement development in agriculture and woodlands. The GNSDF has set out to expand the agricultural corridor. It also targeted urban foodsheds and a network of green infrastructure.

If we focus on the link between policies and environmental change, we consider policy indicators, when implemented, that will preserve the RFAZ landscape and benefit humans through ecosystem services. The critical element of policies considered in this paper is introducing financial incentives to landscape users. However, is this in line with broader concerns of environmental protection, biodiversity conservation, watershed protection, and later climate change protection? Considering the production pillar of the RFAZ landscape (Table 3), SAP, ROPP, NSSP, FASDEP I, and FASDEP II are regarded as sustainable production, land management, and production systems in their policy such that the policies seek to provide incentives to farmers to improve and expand agriculture production. However, the GNSDF considered only land management a crucial spatial development and planning indicator. Regarding the landscape conservation pillar, the NSSP, FASDEP I, and FASDEP II satisfy the conservation indicators by considering biodiversity, natural resource management, and ecosystem services. Unlikely SAP, ROPP does not assume any indicators under the landscape conservation pillar. The SAP and ROPP focus mainly on agricultural production without paying rigorous attention to conservation. The GNSDF considered only natural resource management in the policy, leveraging on the need to demarcate lands for agricultural expansion. Again, all the policies considered well-being and infrastructure indicators except human settlement, which GNSDF thought intensively.

3.2. RFAZ landscape dynamics

The overall accuracy assessment of the LULC maps of the study area in 1991, 2008, and 2022 were 91.5%, 76.5%, and 82.5%. The accuracy of the 1991 classified LULC map accords with the reference data compared to 2008 and 2022. The study recorded the lowest producer accuracy, 21.87%, for built-up in the 1991 LULC map, while shrubland and cropland had the most insufficient user accuracy, 47.58%, and producer accuracy, 55.31%, in 2008, respectively. For Oil palm, the study recorded 86.58% user accuracy and 71.42% producer accuracy for the 2022 LULC map. The uncertainties in the LULC maps of the RFAZ and their adjusted areas are presented in Table 4.

3.3. LULC dynamics under SAP, ROPP, NSSP, FASDEP I, FASDEP II, and GNSDF in the Forest agroecological landscape from 1991—2022

The landscape has been classified into wetlands, water bodies, shrublands, forests, oil palms, built-up, croplands, and rubber based on the supervised classification presented in Fig. 3. The statistics on land cover categories for 1991 (a), 2008 (b), and 2022 (c) are shown in Table 5.

In 1991, the landscape was dominated by oil palm plantations (22,847.94 ha), representing 41.19%, followed by forest (9627 ha, 17.35%) and Rubber (8714 ha,15.71%) respectively (Table 5; Fig. 3). The remaining LULC categories, cropland, shrubland, waterbody, built-up, and wetlands, covered 13.72%, 6.67%, 1.95%, 1.62%, and 1.27% of the land area, respectively. In 2008, oil palm plantations remained the dominant LULC category, constituting 20,776 ha (37.45%) of the study area. This was followed by rubber plantation (11,769 ha, 21.21%) as observed in 1991. Cropland also takes up 8918 ha (16.07%) of the total land area, while the built-up area was 1022 ha (1.84%). The area of coverage for the natural LULC categories was made up of 10258 ha

Table 3
Policy Types and Review Indicators.

Landscape Pillars	Landscape Indicators	Policy Types					
		SAP 1983–1990	ROPP 1995–2022	NSSP 1996–2021	FASDEP1 2002–2007	FASDEP II 2007-Present	GNSDF 2015–2035
Production	Sustainable Production	✓	✓	✓	✓	✓	×
	Land management	✓	✓	×	×	✓	✓
	Production systems	✓	✓	✓	✓	✓	×
Conservation	Biodiversity	×	×	✓	✓	✓	×
	Natural resource management	×	×	✓	✓	✓	✓
	Ecosystem services	×	×	✓	✓	✓	×
Livelihood	wellbeing	✓	✓	✓	✓	✓	✓
	Infrastructure	✓	✓	✓	✓	✓	✓
	Human settlement	×	×	×	×	×	✓

✓The policy considered landscape indicators extensively.
×Landscape indicator is not considered in the policy.

Table 4
Accuracy Assessment of the rainforest agro-ecological zone for 1991, 2008 and 2022.

LULC Types	1991		2008		2022	
	User	Producer	User	Producer	User	Producer
Wetland	93.75%	88.23%	89.92%	76.14%	90.25%	83.33%
Waterbody	93.75%	75%	82.60%	89.18%	80%	80.00%
Shrubland	89.23%	79.45%	47.58%	77.92%	40%	54.34%
Forest	89%	91.39%	95.22%	83.51%	92.56%	87.53%
Oil Palm	85%	96.66%	67.55%	63.65%	86.58%	71.42%
Built-up	87.25%	81.87%	89.76%	72%	90.55%	84.56%
Cropland	73.42%	93.16%	49.42%	55.31%	60.25%	60.00%
Rubber	88.81%	90.25%	81.56%	78.99%	80.55%	80.00%
	O A= 91.5%		OA =76.5%		OA= 82.5%	

Note: OA = Overall Accuracy

(18.49%) for the forest, 502 ha (0.90%) for shrubs, and 286 ha (0.51%) for waterbody (Table 5; Fig. 3). In 2022, rubber plantations became the dominant LULC category, covering an area of 21875 ha (39.44%). Oil palm plantations decreased from 20,776 ha in 2008–15137 ha (27.29%) in 2022. The built-up area increased from 1.84% in 2008 to 5.99% in 2022, while shrubs decreased in their area extent (Fig. 3). Forest and croplands, which were increasing, fell in their area extent in 2022. For instance, the forest decreased from 10258 ha (18.49%) in 2008–5868.27 ha (10.56%) in 2022 (Table 5, Fig. 4).

The transition matrix (Table 5) also indicates changes between the various LULC categories for 1991—2008 and 2008—2022. These changes are represented as gross losses and gains indicating land transfer among the land cover categories for the area under study. The total persistence in the land cover accounts for 55,468.62 ha of the entire study area (Table 5).

As shown in Table 6, the net gross gain between 1991 and 2008 for wetland, forest, built-up, cropland, and rubber were 2.19%, 1.18%, 0.21%, 2.23%, and 5.30% respectively. Rubber plantations recorded the highest percentage net gain compared to the other LULC categories in the study area during 1991—2008. This significant gain is spatially shown in Figure 5. Further, areas covered by shrubs, oil palms, and water recorded a net gross loss (Table 6). However, the net gross loss for shrubland (3257.01 ha, 5.87%) was higher than that for oil palm (2108.88 ha, 3.80%) and waterbody (798.30 ha, 1.43%). Between 2008 and 2022, the net gross loss for oil palm (10.02%) was higher than the net loss for croplands (9.85%), forest (7.90%), and waterbody (0.02%). However, rubber plantations recorded a net gross gain of 17.75%. Surprisingly, shrubland recorded a net gross gain (606.24 ha, 1.09%) during the second time interval. The net gross gain (1848.69 ha, 3.33%) for wetlands during 2008—2022 was higher than that recorded in 1991—2008.

3.4. *Intensity analysis*

3.4.1. *Category level Intensity analysis*

Fig. 7 presents results for category level of intensity analysis for 1991—2008 and 2008—2022. In the first-time interval, wetland, waterbody, shrubland, built-up, cropland, and rubber recorded both active losses and gains. Interestingly, forest and oil palm experienced dormant losses and gains in the study. Both shrubland and cropland recorded active gains and losses for the second time, while wetland, waterbody, and forest experienced dormant gains and losses. Built-up and rubber were functional in terms of gains but experienced dormant. As expected, oil palm recorded active losses but was dormant in terms of gains in the landscape.

3.4.2. *Interval level intensity analysis*

Fig. 6 shows the interval-level analysis for 1991—2008 and 2008—2022 time intervals in the study area. The overall annual change of intensity (3.72%) during the first-time interval was relatively slower than the annual change (4.41%) in the second time interval. Bars extending beyond the uniform annual change bar indicate that the shift in intensity was fast, while the bars below indicate a slow change in intensity.

3.4.3. *Transition level intensity analysis*

The transition level intensity observed between LULC categories for 1991—2008 and 2008—2022 is depicted in Fig. 8. It considers gross gains in the study area to estimate the patterns of LULC change. The transition to oil palm targeted shrubland and rubber intensively during both time intervals. Meanwhile, waterbodies and wetlands actively accounted for rubber plantation cover. Also, oil palm targeted croplands during the first-time interval. The transition intensities for built-up intensively targeted wetland shrublands and cropland during the first interval but targeted only waterbody during the second interval. The transition to rubber-targeted wetlands, waterbodies, and forested areas

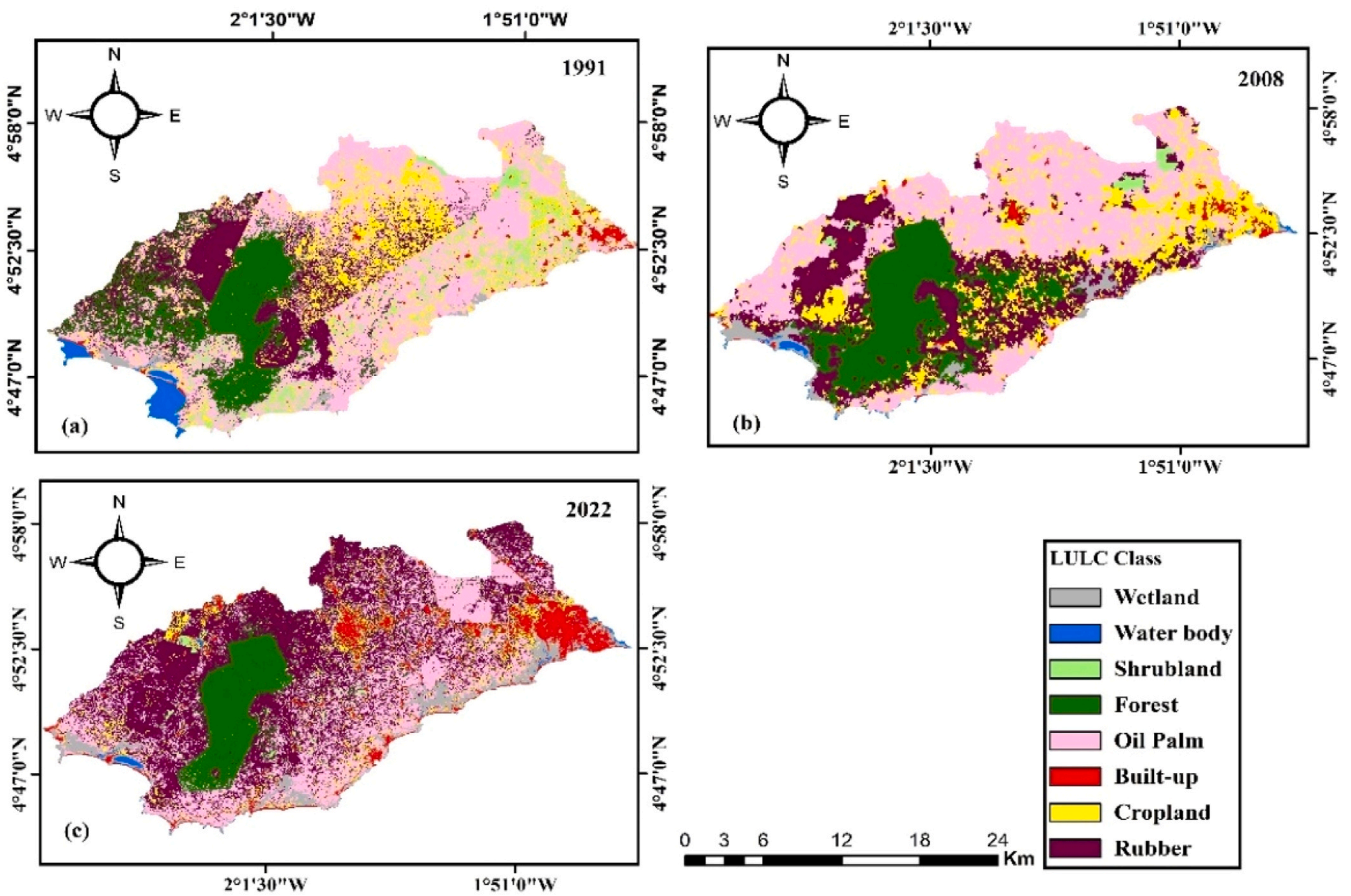

Fig. 3. LULC maps of Rainforest Agro-Ecological Zone of Ghana for 1991(a), 2008(b) and 2022 (c).

Table 5
LULC Transition Matrices of Rain Forest Agroecological Zone for 1991—2008, 2008—2022.

					2008					1991—2008
	WL	WB	SL	F	OP	BU	CL	RB	1991 Total	GL
WL	**143.19**	85.59	0.09	128.88	110.97	32.22	60.57	151.92	713.43	570.24
WB	366.12	**42.39**	0	279.09	17.73	19.71	37.17	324.27	1086.48	1044.09
SL	183.6	12.78	**114.21**	452.16	1260.09	122.22	934.38	681.03	3760.47	3646.26
F	32.49	0.9	32.04	**4999.59**	1662.84	28.17	933.57	1909.35	9598.95	4599.36
OP	851.49	102.15	264.24	2401.56	**10473.48**	395.55	4102.47	4257.54	22848.48	12374.5
BU	94.41	17.37	3.15	47.43	216.9	**103.86**	331.2	95.31	909.63	805.77
CL	194.31	24.57	23.49	563.58	3934.26	237.69	**1455.84**	1287	7720.74	6264.9
RB	64.71	2.97	66.24	1383.21	3062.79	90.54	1102.05	**3057.93**	8830.44	5772.51
2008 total	1930.32	288.72	503.46	10255.5	20739.06	1029.96	8957.25	11764.35	**55468.62**	35077.59
GG	1787.13	246.33	389.25	5255.91	10265.6	926.1	7501.41	8705.88	110936	70155.2
					2022					2008—2022
	WL	WB	SL	F	OP	BU	CL	RB	2008 Total	GL
WL	**1364.04**	76.41	0	6.12	270.36	123.57	35.28	54.54	1930.32	566.28
WB	71.82	**179.82**	0	0	1.89	35.01	0.18	0	288.72	108.9
SL	0.63	0	**36.36**	1.44	355.14	7.74	6.75	95.4	503.46	467.1
F	0.27	122.67	111.87	**5412.33**	2207.61	13.23	136.98	2250.54	10255.5	4843.17
OP	840.69	9.09	440.55	233.28	**6400.17**	1090.98	1615.95	10108.35	20739.06	14338.9
BU	47.97	2.07	3.33	3.15	13.32	**902.97**	26.01	31.14	1029.96	126.99
CL	718.02	7.47	179.28	50.67	2270.34	1799.82	**907.65**	3024.54	8957.79	8050.14
RB	613.17	0.81	338.49	161.28	3658.95	181.35	762.66	**6047.1**	11763.81	5716.71
2022 Total	3656.61	398.34	1109.88	5868.27	15177.78	4154.67	3491.46	21611.61	**55,468.62**	34218.18
GG	2292.57	218.52	1073.52	455.94	8777.61	3251.7	2583.81	15564.5	11,0937	68436.4

Note: WL=wetlands, WB=waterbody, SL=shrubland, F=forest, OP=oil palm, BU=built-up, CL=cropland, RB=rubber, GL= Gross loss, and GG= gross gain

in the first-time interval. Surprisingly, the oil palm category is the only land cover that has contributed to the transition to a rubber plantation in the landscape during the second time interval, as shown in Fig. 8.

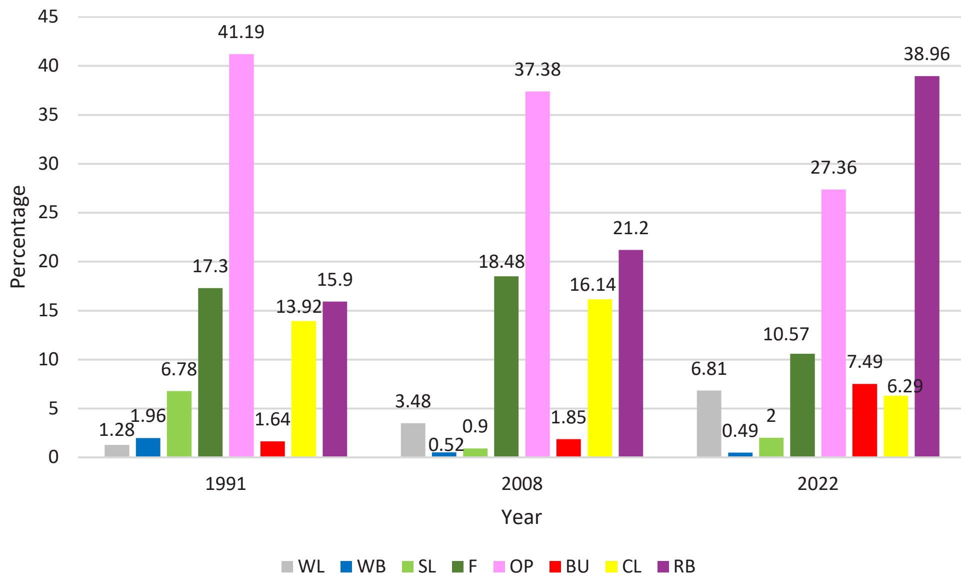

Fig. 4. Spatial extent of LULC categories in percentages (%).

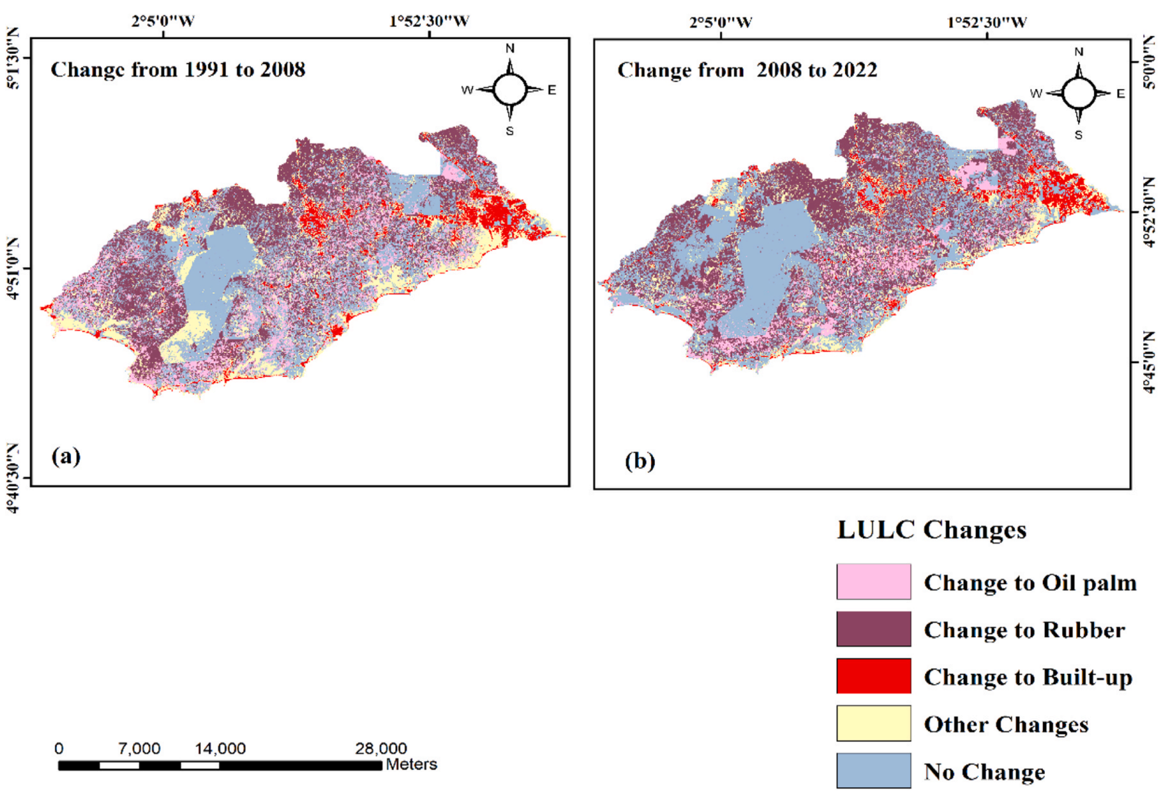

Fig. 5. Change detection map of the study area from 1991to 2008 (a) and (b) 2008–2022.

4. Discussion

4.1. Land use/ land cover dynamics of the study landscape

The landscape dynamics of the rainforest agroecological zone represent a nexus challenge transforming the discursive context of policy adaptation. Various discourses have emerged regarding what indicators developing countries should use to evaluate and understand the transformative governance of their landscape. The landscape changes were understood through the mapping and analysis of eight (8) LULC categories (Wetlands, waterbodies, shrublands, forest, oil palm, built-up, croplands, and rubber) for 1991—2008 and 2008—2022. The overall annual change in the LULC during the implementation of SAP, ROPP, NSSP, and FASDEP I was slower in the first-time interval (1991–2008) than in the second-time interval (2008—2022) where FASDEP II and GNSDF were operationalised in the landscape. The intensive transformation of the landscape in the second time interval is consistent with Ghana's economic and population growth (Duku et al., 2021), which was averagely faster than sub-Saharan Africa's population growth rate in 2008 (Broadberry and Gardner, 2019). This finding is

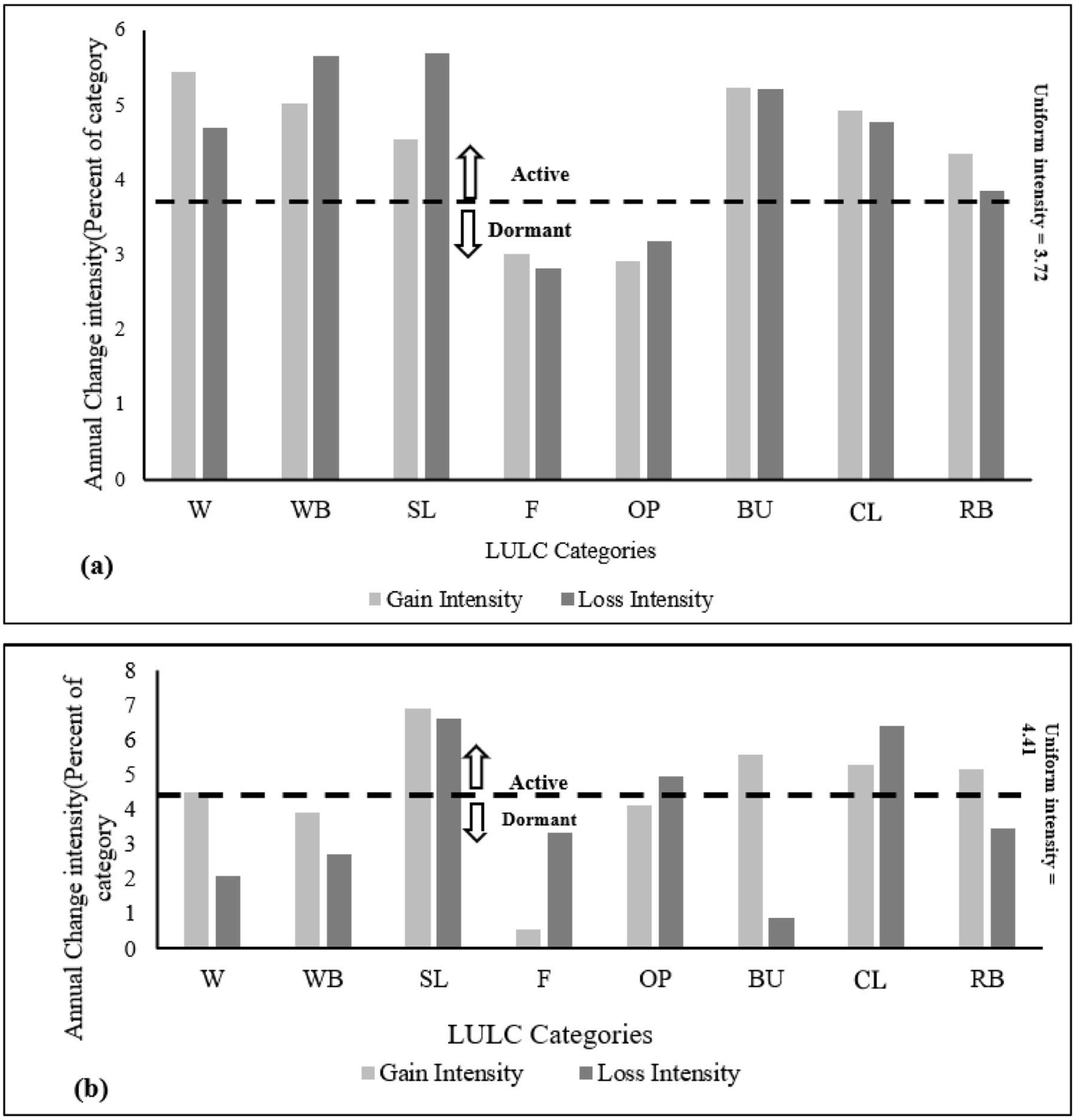

Fig. 6. Interval level intensity change for 1991–2008 and 2008–2022.

Table 6
Net gross gain and loss of LULC categories in hectares (ha) and percentages (%) during 1991—2008 and 2008—2022.

LULC Categories	Net loss/gain 1991–2008 (ha)	Percent Change (%)	2008–2022 (ha)	Percent Change (%)
Wetland	1216.89	2.19	1848.69	3.33
Waterbody	-798.30	-1.43	-12.78	-0.02
Shrubland	-3257.01	-5.87	606.24	1.09
Forest	656.55	1.18	-4387.23	-7.90
Oil Palm	-2108.88	-3.80	-5561.29	-10.02
Built-up	120.33	0.21	3124.71	5.63
Cropland	1237.05	2.23	-5466.33	-9.85
Rubber	2943.37	5.30	9847.80	17.75

Note: Negative values under the change depict net gross loss, and positive values depict net gross gain for the LULC category. Net gross gain/loss Area of cover for a landcover category in the present year – the area of cover for a LULC category in the previous year.

consistent with the results of a previous study (Asante-Yeboah et al., 2022), which revealed that LULC changes in the second time interval are faster than the first time interval of the study landscape. The observed intensity of LULC dynamics over the 31 years posits that underlying processes of the landscape dynamics were rapid in the study landscape. The insight from the observed intensity indicates the need for an integrative landscape management approach. Regarding spatial extent, the study revealed that agricultural LULC categories (oil palm, cropland and rubber) were the major LULC types in 1991, 2008 and 2008. These LULC categories accounted for about 70% of LULC change in the landscape. A study by Asante-Yeboah et al. (2022) revealed that the rubber LULC category became the dominant land cover in 2020. Kankam et al. (2021) indicated a similar trend, which pointed to oil palm and rubber as the dominant land cover in all three-time points of the study period. These findings show significant variation in the transition intensity of LULC categories across time and space. This development calls for a specific assessment to unveil the dynamic trends and processes that drive the LULC changes in the landscape.

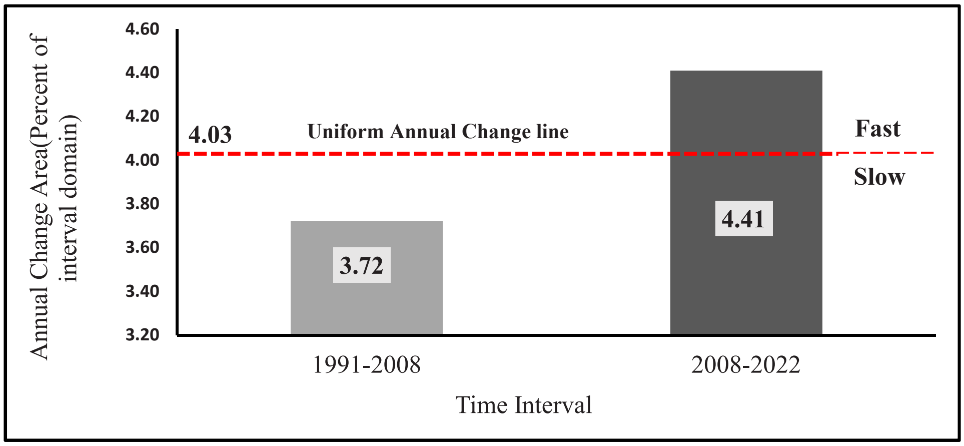

Fig. 7. Categories level intensity change for (a)1991—2008 and (b) 2008—2022.

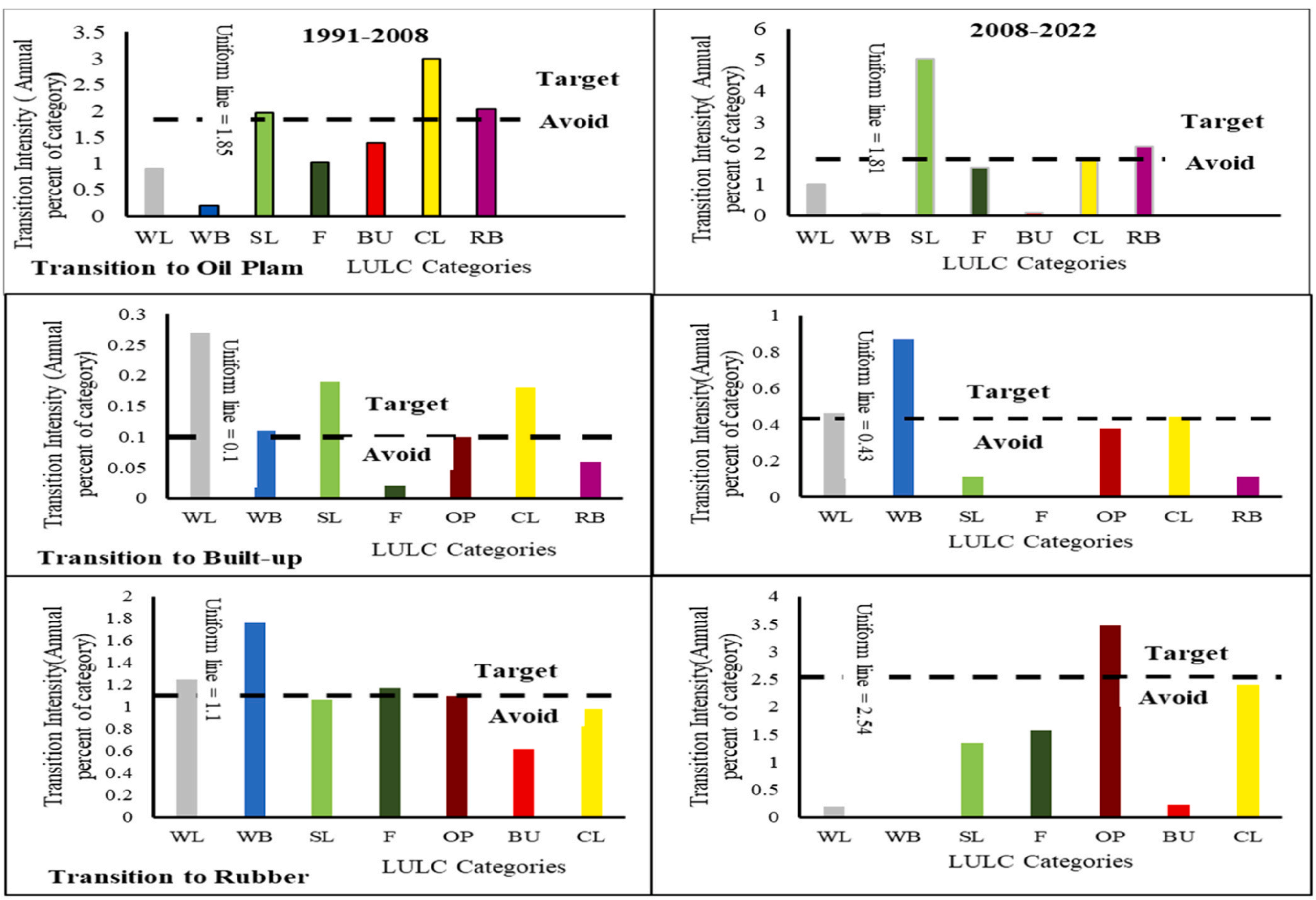

Fig. 8. Transition level intensity change for 1991—2008 and 2008—2022.

4.2. The implication of agriculture-land use policy on landscape dynamics

Agriculture policies or interventions are tasked with solving issues related to agriculture, while land use policies seek to tackle spatially related problems. The study reviewed SAP (1983–1990), ROPP (1994−2022), NSSP (1995−2022), FASDEP I (2002–2007), FASDEP II (2007-Present), and GNSDF (2015−2035), which teased out factors contributing to LULC changes in the study landscape.

The rapid expansion of the agricultural landscape started in the light of SAP, where there was an urgent need for industrialisation to revamp Ghana's economy. Though agricultural activities like farming dominated during the SAP period, the intensity of changes in the landscape was minimal compared to recent times. The commercialisation of agroforestry by the government and private sectors has contributed to rapid changes in the landscape of Ghana's agroecological zone. In the mid-2000 s, the development of built-up areas was driven by recent policies and interventions. For instance, between 2008 and 2022, the government implemented FASDEP II and GNSDF policies to transform the agricultural sector and develop infrastructure. Regarding FASDEP I and FASDEP II, the government focused on developing irrigation, mechanisation services, and value chains and intensifying farmer-based organisations and outgrower schemes. The shift in policy direction influences production and contributes to changes in the agricultural landscape.

The ROPP and NSSP have contributed to most of the land in the rainforest agroecological landscape. The ROPP and NSSP have components that drive farmers' adoption of the policy in the landscape. These components include the provision of agriculture inputs like agrochemicals such as fertilisers and pesticides, access to credit, market and trade, and land tenure (Agyeman et al., 2014). Under the ROPP and NSSP, farmers were provided with agricultural inputs such as fertilisers, pesticides, and extension officers to facilitate their activities. The policy also supports smallholder farmers with financial capital through loans. These benefits have encouraged smallholder farmers to use cash crops like rubber and oil palm. In 1991, before the implementation of ROPP, NSSP, and GNSDF, oil palm was the most dominant land cover in the study landscape, which confirmed a study done by Asante-Yeboah et al. (2022) stressing that oil palm plantation is the most cultivated cash crop among smallholder farmers in the study landscape. During this same period (before 1991), the SAP was implemented in the RFAZ. The higher acreage of oil palm could be attributed to the fact that most of the farmers had limited knowledge of rubber cultivation and the fear of investing in rubber plantations, which was vulnerable to their sustainable livelihood in the short term. An in−depth interview with farmers revealed that rubber takes at least seven years to mature for harvest. Though there is a marginal rise in the oil palm farmers population under the NSSP, as expressed in Adeho (2015), oil palm land cover consistently experienced dormant and active loss intensity during the first- and second-time intervals in the study landscape. This may be attributed to the low income generated from oil palm. The agreed market price for oil palm was lower than rubber, which might lead to decreased oil palm cultivation. Implementing ROPP and GNSDF could also contribute to the widespread of rubber plantations and built-up land covers. Further, implementing ROPP has changed farmers' perception of rubber plantations. Thus, before the ROPP was introduced, smallholder farmers assumed that rubber plantations could not meet their expectations at the end of the farming season. However, the sanitisation and education on sustainable income from rubber plantations among smallholder farmers in the communities, together with an incentive package for rubber plantations, has resulted in a higher profit margin for rubber growers. The resurrection of rubber production among the farmers has greatly overturned oil palm production in the landscape, contributing to active gains in the intensity of rubber land cover during the second interval. It is a sign that the availability of market and trade for purchasing rubber latex has also influenced most farmers to get involved in rubber cultivation, translating to the conversion of other land covers to rubber land cover. The stakeholder's engagement in the study landscape pointed out that access to land for cash crop cultivation, specifically rubber, increased the willingness of smallholder farmers to utilise any available lands for rubber plantations. Thus, landowners are willing to lease lands for rubber plantation, even if it is meant for other purposes. The ROPP made smallholder farmers believe that rubber provides sustainable income compared to oil palm plantations. This translated to cultivating acreage of ecological and arable lands for rubber plantations in the study landscape. The GNSDF, which facilitates spatial planning and development of the study landscape, contributes to built-up development. The net gain of built-up in the first time interval is lower than in the second. After GNSDF was implemented, the built-up areas gradually increased from 1.85% in 2008 to 7.49% in 2022. This increase may be attributed to the rise in population through the influx of migrants for cash crop farming and other job opportunities. Sustainable income from the cultivation of cash crops has helped farmers improve their well-being through housing. The GNSDF also helps develop significant infrastructures in the study landscape. The ROPP and NSSP initiators like GREL and Norpalm have provided some basic facilities like schools, health centres, and roads as part of corporate social responsibility and saw an expansion in built-up land cover in 2022.

4.3. Implication for environmental sustainability and policy development

Per our assessments, the LULC change results play a significant role in different agroecological studies, providing empirical evidence about how other agricultural policies work for forest landscape resilience and sustainable development. To sustain our environment, this also provides a baseline to engineer discussions on landscape changes during agriculture or environmental policy design and intervention strategies to be incorporated. It is expected that the output of this work will be applied in different ecological settings, thereby filling gaps in the literature and the need for comprehensive and integrated policy development to promote landscape neutrality.

5. Conclusion

The landscape has experienced tremendous changes through agricultural land use policies. These changes were understood through intensity analysis of LULC categories of the stud landscape. The study indicated oil palm as the dominant land cover category contributing to landscape changes before implementing agriculture-land use policies. The intensity analysis revealed that the overall annual change of the LULC was lower than the overall yearly change in the second time interval. Meanwhile, the policies were implemented in the first-time interval. This indicates that external factors like agriculture policies influence LULC, which increases the rate of LULC changes in the second time interval. The policy review shows that smallholder farmers were more susceptible to rubber cultivation than oil palm, which translated to improved income levels. Oil palm began to shrink in the landscape because the ROPP was more flexible than NSSP. The GNSDF, together with a persistent increase in farming population from the farming communities, has expanded built-up areas in the landscape. The GNSDF helps in the planning and providing infrastructures for the expansion of built-up. Though agriculture-land use policies are meant to improve the livelihood of smallholder farmers, the deterrent development to ecological growth of the landscape through these policies can threaten ecological connectivity if not correctly implemented in the study landscape. The study recommended that agricultural land use policies strictly protect forest reserves and water bodies in the landscape. This will enhance proper planning and management of the agroecological landscape at the sub-national level.

CRediT authorship contribution statement

Wonder Kofi Adzigbli: Writing – review & editing, Data curation, Conceptualization, Formal analysis, Methodology, Validation, Visualization, Writing – original draft. **Eric Duku:** Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization, Writing – review & editing. **Gerald Atampugre:** Writing – review & editing, Supervision, Validation. **Christine Fürst:** Writing – review & editing, Funding acquisition. **Benjamin Kofi Nyarko:** Writing – review & editing, Validation, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The authors do not have permission to share data.

Acknowledgements

This research received a fieldwork grant from the SESASA Project (https://sesasa.eli-web.com/) and thus contributed to the Project, which was funded by A long-term EU-Africa research and innovation partnership on food and nutrition security and sustainable agriculture (LEAP-AGRI) (project Grant Agreement number: 727715). The SESASA project aims to develop a "System of Systems" concept to assess land-use and land-management change scenarios to strengthen sustainable water management. All contributions from colleagues towards the realisation of this paper are much appreciated. Our appreciation goes to the anonymous reviewers for their constructive comments that contributed to improving our paper.

References

Adeho, C., 2015. FDI Outcomes, local conditions and development Narratives: a Case of norpalm Ghana limited and small-scale farmers in the oil palm industry in Ghana.

Agyeman, B.A.S., Asuming-Brempong, S., Onumah, E.E., 2014. Determinants of income diversification of farm households in the Western Region of Ghana.Quarterly Journal of International Agriculture 53 , (1), 55-72.

Akinyemi, F.O., Mashame, G., 2018. Analysis of land change in the dryland agricultural landscapes of eastern Botswana. Land Use Policy 76, 798–811.

Aldwaik, S.Z., Pontius, R.G., 2012. Intensity analysis to unify measurements of size and stationarity of land changes by interval, category, and transition. Landsc. Urban Plan. *106* (1), 103–114. https://doi.org/10.1016/j.landurbplan.2012.02.010.

Alshari, E.A., Gawali, B.W., 2021. Development of classification system for LULC using remote sensing and GIS. Glob. Transit. Proc. *2* (1), 8–17. https://doi.org/10.1016/j.gltp.2021.01.002.

Asante-Yeboah, E., Ashiagbor, G., Asubonteng, K., Sieber, S., Mensah, J.C., & Fürst, C. (2022). Analyzing Variations in Size and Intensities in Land Use Dynamics for Sustainable Land Use Management: A Case of the Coastal Landscapes of South-Western Ghana. 1–28.

Asuming-Brempong, S., 2013. Policy initiatives and agricultural performance in post-independent Ghana. J. Soc. Dev. Sci. *4* (9), 425–434. https://doi.org/10.22610/jsds.v4i9.781.

Boohene, R., Peprah, J.A., 2011. Women, Livelihood and Oil and Gas Discovery in Ghana: an exploratory study of cape three points and surrounding communities. J. Sustain. Dev. *4* (3), 185–195. https://doi.org/10.5539/jsd.v4n3p185.

Broadberry, S., Gardner, L., 2019. Economic growth in sub-Saharan Africa, pp. 1885–2008.

Christiaensen, L., Rutledge, Z. and Taylor, J.E., 2020. The future of work in agriculture: Some reflections. *World Bank Policy Research Working Paper*, (9193).

Duku, E., Mattah, P.A.D., Angnuureng, D.B., 2021. Assessment of land use/land cover change and morphometric parameters in the keta lagoon complex ramsar site, Ghana. Water (Switz.) *13* (18). https://doi.org/10.3390/w13182537.

Duku, E., Agbeko, P., Mattah, D., Bapentire, D., 2022. Assessment of wetland ecosystem services and human wellbeing nexus in sub-Saharan Africa: empirical evidence from a socio-ecological landscape of Ghana. Environ. Sustain. Indic. *15* (May), 100186 https://doi.org/10.1016/j.indic.2022.100186.

Ekumah, B., Ato, F., Ernest, A., Worlanyo, D., Justice, A., Odoi, O., 2020. Assessing land use and land cover change in coastal urban wetlands of international importance in Ghana using Intensity Analysis. *Wetl. Ecol. Manag.*, *5*(Keddy 2010). https://doi.org/10.1007/s11273-020-09712-5.

Ewusi Koomson, J., Donkor, E., Owusu, V., 2022. Contract farming scheme for rubber production in Western region of Ghana: why do farmers side sell? Forests, Trees and Livelihoods 31 (3), 139–152.

FAO World Food and Agriculture – Statistical Yearbook 2023 2023 Rome.https://doi.org/10.4060/cc8166en.

Fletcher, A.J., Reed, M.G. (Eds.), 2022. *Gender and the social dimensions of climate change: rural and resource contexts of the global North*. Taylor & Francis.

Frison, E.A., IPES-Food., 2016. From uniformity to diversity: a paradigm shift from industrial agriculture to diversified agroecological systems. Louvain-la-Neuve (Belgium): IPES, 96 p. https://hdl.handle.net/10568/75659.

GSS, 2014. 2010 Population and Housing Census: District Analytical Report. Ahanta West Municipality.

Gupta, N., Mathew, A., Khandelwal, S., 2020. Spatio-temporal impact assessment of land use / land cover (LU-LC) change on land surface temperatures over Jaipur city in India. Int. J. Urban Sustain. Dev. *12* (3), 283–299. https://doi.org/10.1080/19463138.2020.1727908.

Jaya, L.M.G., Saputra, R.A., Idrus, S.H., 2022. Using Support Vector Machine To Identify Land Cover Change During Covid-19 Pandemic In Komodo National Park, Indonesia. *Geography, Environment, Sustainability 15* (3), 70–79.

Kankam, S., Inkoom, J.N., Koo, H., Fürst, C., 2021. Envisioning alternative futures of cultural ecosystem services supply in the coastal landscapes of Southwestern Ghana, West Africa. Socio-Ecol. Pract. Res. *0123456789*, 744–745. https://doi.org/10.1007/s42532-021-00090-7.

Khan, M.R., Roberts, J.T., 2013. Adaptation and international climate policy. Wiley Interdisciplinary Reviews: Climate Change 4 (3), 171–189.

Kociszewski, K., 2018. Sustainable development of agriculture-theoretical aspects and their implications. *Economic and Environmental Studies*, *18*(3 (47)), pp.1119-1134.

Mallupattu, P.K., Sreenivasula Reddy, J.R., 2013. Analysis of land use/land cover changes using remote sensing data and GIS at an Urban Area, Tirupati, India. Sci. World J. *2013*, 1–7. https://doi.org/10.1155/2013/268623.

Milder, J.C., Hart, A.K., Dobie, P., Minai, J., Zaleski, C., 2014. Integrated Landscape Initiatives for African Agriculture, Development, and Conservation: A Region-Wide Assessment. World Dev. *54* (February 2014)), 68–80. https://doi.org/10.1016/j.worlddev.2013.07.006.

MoFA, 2007. Food and Agriculture Sector Development Policy (FASDEP II). Available online: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC144957 (Accessed on 30 January 2022).

OECD/FAO, 2016. Agriculture in Sub-Saharan Africa: Prospects and challenges for the next decade. *OECD-FAO agricultural*. outlook 2016–2025, 59–95.

Paglietti, L., Sabrie, R., 2012. Outgrower Schemes: Advantages of Different Business Models for Sustainable Crop Intensification. Ghana Case Studies. FAO Investment Centre: Learning from investment practices, pp. 1–12.

Pedroli, Bas, Berien Elbersen, Pia Frederiksen, Ulf Grandin, Raimo Heikkilä, Paul Henning Krogh, Zita Izakovičová, Anders Johansen, Linda Meiresonne, and Joop Spijker. "Is energy cropping in Europe compatible with biodiversity?–Opportunities and threats to biodiversity from land-based production of biomass for bioenergy purposes." *Biomass and Bioenergy* 55 (2013): 73-86.

Sahle, M., Saito, O., 2021. Assessing nature's contributions to people by Jefoure roads for sustainable management in the Gurage socio-ecological production landscape in Ethiopia. Sustainability 13 (7), 3806.

Tanui, J.G. (2015). The Extent of Spatial Temporal Variations in Land Use and its Implications on Forest Ecosystems: A Case of Nandi Hills Forests Kenya. 5(8), 129–140.

Tasser, E., Leitinger, G., Tappeiner, U., 2017. Climate change versus land-use change—what affects the mountain landscapes more? Land Use Policy *60*, 60–72. https://doi.org/10.1016/J.LANDUSEPOL.2016.10.019.

Tewkesbury, A.P., Comber, A.J., Tate, N.J., Lamb, A., Fisher, P.F., 2015. A critical synthesis of remotely sensed optical image change detection techniques. Remote Sens. Environ. *160*, 1–14. https://doi.org/10.1016/J.RSE.2015.01.006.

Viana, C.M., Oliveira, S., Oliveira, S.C., Rocha, J., 2019. Land use/land cover change detection and urban sprawl analysis. In: *Spatial modeling in GIS and R for earth and environmental sciences*. Elsevier, pp. 621–651.

Yaro, J.A., Teye, J.K., Torvikey, G.D., 2018. Historical context of agricultural commercialisation in ghana: changes in land and labour relations. J. Asian Afr. Stud. *53* (1), 49–63. https://doi.org/10.1177/0021909616657368.

Zhou, P., Huang, J., Pontius, R.G., Hong, H., 2014. Land classification and change intensity analysis in a coastal watershed of Southeast China. Sens. (Switz.) *14* (7), 11640–11658. https://doi.org/10.3390/s140711640.