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Smallholder farmers' perceived effects of land use and cover change on provisioning ecosystem services in the savannah ecological zone of Ghana

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ABSTRACT

Ecosystem services are essential for life sustenance but are presently threatened by land use and cover change (LUCC). Meanwhile, policymakers tend to disregard sustainable pathways that enhance ecosystem integrity due to limited empirical evidence of the impacts of LUCC on provisioning ecosystem services. The existing studies largely rely only on geospatial data or use proxy variables without integration of qualitative information. This study employed a blend of geospatial and qualitative approaches to analyse the spatiotemporal dynamics of LUCC and the perceived impact on provisioning ecosystem services in the savannah zone of Ghana. The findings reveal an expansion of cultivated area from 4.59 km² to 178.63 km² and a decrease in wooded savannah area from 176.022 km² to 29.22 km² between 1990 and 2020 in the Bongo district. Declines in wooded savannah area from 471.685 km² to 258.38 km² and expansion of cultivated area from 5.79 km² to 123.80 km² from 1990 to 2020 were also observed in the KNW district. In synch with the satellite data, farmers observed expansion in agricultural areas at the expense of wooded savannah area over the past decades. Though farmers highly depend on ecosystems for livelihood needs, the capacity of the ecosystems to continually support their livelihood requirements has decreased over the past decade, and this has resulted in substantial declines in vital provisioning ecosystem services such as cereals, fuelwood, fodder/forage, grazing fields, medicinal plants, wild edible fruits and vegetables. To ameliorate decreasing provisioning ecosystem services, environmental governance policies should promote strategies that restore degraded ecosystems.

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KEYWORD Farmers; perceived; effects; land use/cover change; ecosystem-provisioning services; Ghana

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1. Introduction

Human benefits (both material and non-material) that are derived from ecosystems are considered as ecosystem services (Bennett et al., 2015; Karki et al., 2018; Wang et al., 2018). Ecosystem services are vital for life sustenance but are currently threatened by land use and cover change (LUCC) (Smith & Sullivan, 2014; Tolessa et al., 2017). Ecosystem services have become cardinal research arena in ecology and allied fields (Costanza et al., 2017). Global endeavours by The Economics of Ecosystems and Biodiversity (TEEB) (TEEB, 2013), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Díaz et al., 2015), and the Millennium Ecosystem Assessment (MEA) (MA, 2005) have encouraged local-level studies and advocated approaches that integrate local actors' perspectives with scientific information in the assessment of landscapes and ecosystems (Kleemann et al., 2017). Human activities have had profound effects on land use/cover and land resources (Emiru et al., 2018). LUCC is the prime driver of global environmental change (Song et al., 2018) which has substantially affected biodiversity and diverse ecosystem services (Rodríguez-Echeverry et al., 2018).

The impact of changing land use and cover on ecosystem services and human-wellbeing of rural populations are not recognized by many policy-makers in the developing world (Chettri et al., 2021). Conversely, rapid population and associated increasing demand for ecosystem services will further weaken the capacity of the landscape to continually deliver ecosystem services for the present and future generations (Fedele et al., 2017; Lu et al., 2018). Meanwhile, decision-makers in the less developed countries have mostly prioritized short-term growth pathways and disregard sustainable environmental governance pathways that enhance ecosystem integrity (Ruckelshaus et al., 2015). Local resource users will not take concrete efforts to implement planned ecosystem-based adaptations in response to the depletion of ecosystem services unless the services are assessed, and the changing landscape trends recognized (Chettri et al., 2021; Dasgupta, 2021). The United Nations Sustainable Development Goals (SDGs) and the Nationally Determined Contributions (NDCs) can only be achieved when the depletion of important landscapes and ecosystems is halted, degraded landscapes regenerated, and ecosystem services exploited sustainably (Scharlemann et al., 2020). Hence, renewed calls for local-level landscape and ecosystem services assessment are necessary to support decision-making and design of plans to restore the capacity of landscapes to deliver ecosystem services and support human livelihoods (Wu, 2021). This paper addresses the question: What are the trends of LUCC and its perceived impacts on provisioning ecosystem services?

Studies on impact of LUCC on ecosystem services abound (Hasan et al., 2020; Song & Deng, 2017; Tolessa et al., 2017). While many of the studies specifically centre on negative impacts of LUCC on air and water quality and natural habitat (He et al., 2019; Jin et al., 2015; Wang et al., 2023), or how LUCC has altered ecosystems and potential losses of biodiversity (Allan et al., 2015; Barnes et al., 2017; Cousins et al., 2015), few focus on the impacts of LUCC on provisioning ecosystem services, which have a bearing on local livelihoods and rural economy (Kamwi et al., 2015). In Ghana, the impacts of LUCC on provisioning ecosystem services have not been investigated except few studies that have been conducted on impacts of urban expansion on green spaces and urban ecosystem services (Asabere et al., 2020; Puplampu & Boafo, 2021), impact of LUCC on water quality (Tahiru et al., 2020) and ecological sustainability (Akubia et al., 2020). Other studies in the Southern part of Ghana focus on overall susceptibility of forest resources to LUCC (Asibey et al., 2020; Kantanka et al., 2023) and the driving process of LUCC affecting the economy (Acheampong et al., 2018; Antwi-Agyei et al., 2019).

Generally, most of the existing studies typically relied on only geospatial data in the assessment of LUCC trends without triangulation with qualitative information from local actors' historical knowledge and experiences of physical patterns. Although the geospatial approach can measure the rate, extent, spatial and temporal patterns of LUCC accurately, when used alone without ground truthing is inept in providing in-depth insights of primary forces of LUCC (Seppelt et al., 2011). Again, many of the studies have been conducted on a broader scale with larger spatial recommendation domain and do not differentiate between resilient and vulnerable zones to environmental change. Further, most of these siloed studies in their assessment of LUCC impacts on ecosystem services mainly rely on secondary data or use proxy variables to model based on assumptions that may not be accurate across all contexts, hence their findings are not backed by empirically driven primary data gathered from local resource users.

The fragile savannah ecological zone of Ghana has undergone significant changes due to anthropogenic activities (Aniah et al., 2023; Derbile et al., 2022; Kleemann et al., 2017). These changes have weakened the capacity of the savannah ecosystem to support biodiversity and ecosystem services provision, which presents significant impediment to sustainable rural livelihoods (Boafo et al., 2016; Mul et al., 2018). Investigating the LUCC dynamics and changes impacting on provisioning ecosystem services is crucial for ecological protection and sustainable landscape governance for present and future generations. Again, assessing the perceived effects of LUCC on provisioning ecosystem services is essential for understanding the intricate relationship between human activities and the natural environment, which can inform resource decision-making, nature conservation, promote sustainable development and safeguard human-

wellbeing. This paper sets out to assess (using objective-through change detection and subjective-through perception analysis) LUCC dynamics over the last three decades (between 1990 and 2020) and the perceived effects of LUCC on provisioning ecosystem services in the savannah ecological zone of Ghana. The paper is divided into five sections. The introduction [section 1](#) is followed by [section 2](#) which contains a brief profile of the study area, a discussion of the conceptual framework and a description of the materials and methods used. [Section 3](#) provides the results while the discussion of the findings is presented in [section 4](#). [Section 5](#) concludes the paper.

2. Materials and methods

2.1. Study sites

The study sites for this paper are Bongo and Kassena-Nankana West (KNW) districts in the Upper East Region (UER) of Ghana ([Figure 2](#)). The UER lies between longitude 0° and 1° West, and latitudes $10^{\circ} 30'N$ and $11^{\circ}N$. The Bongo district is located between latitude $10.50^{\circ} N$ to 11.09 and longitudes $0.45^{\circ} W$, while the KNW district is located between longitude 01.10° West and latitude 10.97° North (Ghana Statistical Service, [2021](#)). The Bongo district has a total population of 120,254 with a land area of 488 KM^2 . Educational levels are relatively low with literacy rate of 45%. More than 80% of the population derive their livelihood from crop farming and livestock rearing. Poverty levels are generally high with about 36.1% of the population falling below the poverty line (Ghana Statistical Service, [2021](#)). The KNW district has a total population of 90,735 people with a total land area of $1,004 \text{ KM}^2$. Approximately 24.8% of the population falls below the poverty line. Agriculture (crop farming and livestock rearing) is the major livelihood activity, employing 68.7% of the population (Ghana Statistical Service, [2021](#)).

The depiction of emblematic cases of LUCC formed the basis for the selection of study sites. A Normalised Difference Vegetation Index (NDVI) scrutiny tinted the Bongo district as the prime area with severe landscape changes and the KNW district as the area that contains the highest amount of vegetation cover, hence the selection of these two distinct study sites for comparative analysis (Aniah et al., [2023](#)). The Bongo district has the highest population density of $289.8/\text{km}^2$ in the UER compared to the regional average of $129/\text{km}^2$ and the KNW district density of $97.64/\text{km}^2$ (Ghana Statistical Service, [2021](#)). Wardell ([2005](#)) study suggests that the semblance of resilience to LUCC in the KNW district is due to the occurrence of the sleeping sickness (*Glossina*) and river blindness (*Simulium damnosum*) blackfly complexes which moulded the establishment of forest reserves by colonial government.

2.2. Ecosystem service cascade (ESC)

The study adopts the ecosystem service cascade (ESC) framework propounded by Haines-Young and Potschin (2010), which provides understanding on the nexus between ecological systems and human well-being. The ESC is a tool that explains the production chain that connects biophysical processes and structures and the ecological systems on one side and fundamental elements of human well-being on the other side, with a sequence of five transitional steps spanning the natural ecosystem and the human ecosystem (Potschin-Young et al., 2018).

The initial step of the ESC designates the biophysical processes and structures of an ecosystem such as woodland, shrub or grass land (Figure 1). Precise function of the ecosystem (step 2) is obtained from the natural ecosystem, which may include the production of biomass. Ecosystem function in this light refers to the capacity of the ecosystem to generate potentially useful services for humankind. The third stage of the ESC specifies the level at which the ecosystem functions are transformed into services useful for humankind. The third step incorporates socially recognised necessities such as harvestable products, air, water purification, and flood control into the ESC. The fourth step of the ESC defines the diverse variety of benefits (e.g. health and safety) humankind obtains from ecosystem services. In the final stage of the ESC, the benefits humankind obtains from ecosystem services are valued using economic and social parameters such as willingness to pay for both material and non-material benefits (harvestable products, spiritual enrichment, leisure, and recreation) (Potschin-Young et al., 2018).

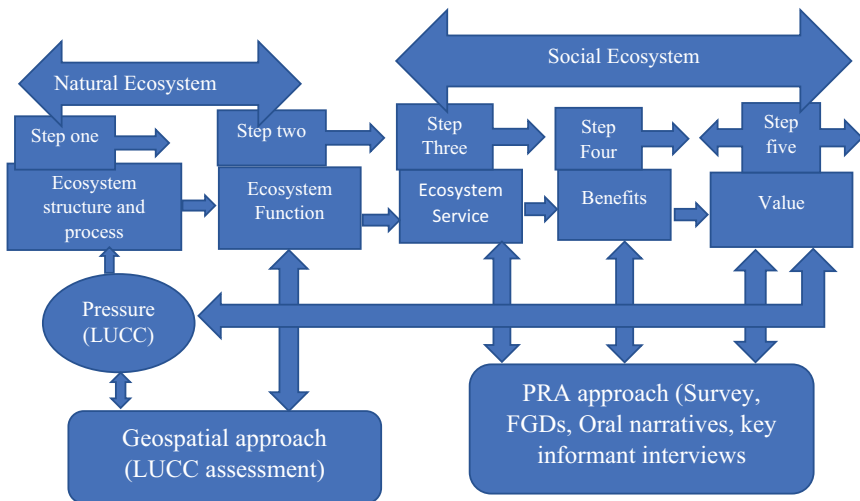


Figure 1. Ecosystem service cascade. **Source:** Adapted from Haines-Young and Potschin (2010).

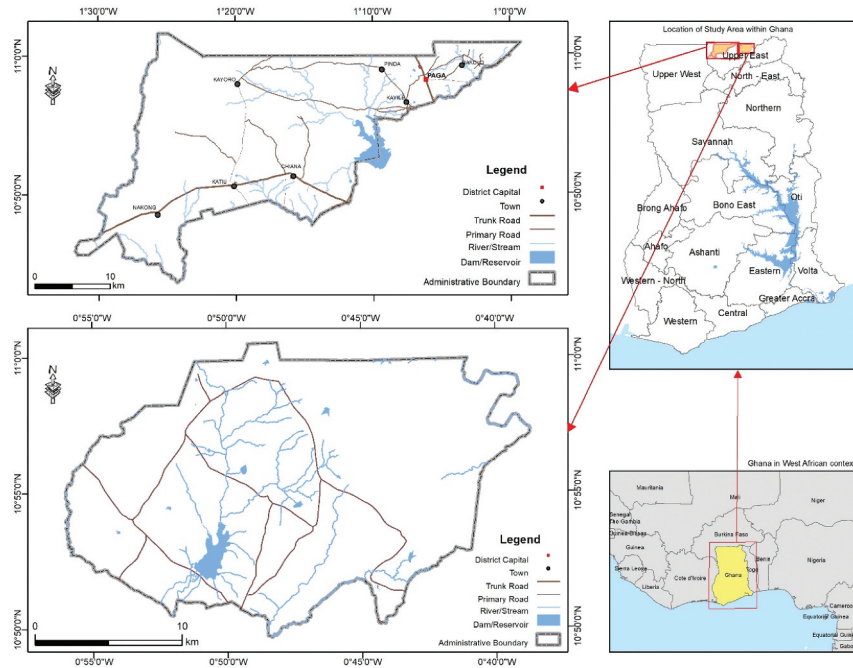


Figure 2. The study districts in the UER of Ghana.

This paper assumes that LUCC is an eminent driver that exerts pressure on the ecosystem structure and processes (step 1), weakens the capacity of the ecosystem to function (step 2) and consequently reduces the availability and access to ecosystem services (step 3) and by implication ecosystem benefits (step 4). The blend of geospatial (step 1 to step 2) and participatory rural appraisal methods (PRA) (step 3 to step 5) solves the often-mentioned limitation of the ESC model as being too naturalistic. Involving human agency in this study improves understanding of the nexus between ecological and social systems (Hausknost et al., 2017). For instance, perceptions can influence the willingness to give compensation for ecosystem services or the governance mechanisms adopted for sustainable utilisation of ecosystem services. Also, planned local- and national-level policy actions can limit the pressure exerted on ecosystem services structure and processes (Hausknost et al., 2017; Zhang et al., 2022).

2.3. Geospatial analysis

To identify the spatiotemporal dynamics of the two study sites (Bongo and KNU) in the UER for the three-decade period, LUCC analysis was conducted. The paper acquired a 30 m spatial resolution Landsat Multi-

Spectral Scanner (MSS), Thematic Mapper (TM), the Enhanced Thematic Mapper (ETM+) and the Operational Land Imager (OLI) and Thermal Infrared Sensors (TIRS) data of four historical years (1990, 2000, 2010 and 2020) from Global Visualization Viewer (GloVis). After a successful acquisition of Landsat data, we performed atmospheric and radiometric corrections to ensure that the information generated from the satellite data is accurate. The ENVI 5.2 platform was used to perform the atmospheric and radiometric corrections. Both current and historical expert knowledge of the study area's physical patterns were combined with the training sites data to describe the feature classes. The identified LUCC categories were agriculture, settlement, water bodies, bare soil, wooded savannah and shrub and tree savannah.

We employed the Random Forest Algorithm (RFA) package in R to perform the classification. The training samples were extracted using google earth historical function. For every study year, about 150 training samples were extracted. We divided the data into training (30%) and test (70%) datasets. We fitted the RFA on the training dataset for each study year using the decision trees number ($n_{tree} = 600$) and the input features number ($m_{try} = 3$) (Aniah et al., 2023). The goal of avoiding the likelihood of overfitting the model guided our selection of the hyperparameters. We employed the trained model for the prediction of the LUCC classes in the test dataset. The accuracy statistic was used to evaluate the performance of the RFA.

The overall accuracy for the Bongo district maps were 87%, 79%, 87% and 93% for the years 1990, 2000, 2010 and 2020, respectively (Table 1). The overall accuracy for the KNW districts maps was 85%, 87%, 90% and 92% for the years 1990, 2000, 2010 and 2020, respectively (Table 1). Based on the test dataset, the trained model was consequently used to simulate the identified 6 LUCC classes for each study year. Four LUCC maps were produced for each of the four study years for both study districts.

2.4. Participatory Rural Appraisal (PRA) methods

The paper employed PRA tools such as key informant interviews, focus group discussions (FGDs), oral narratives, and a structured household survey (Antwi-Agyei, 2012; Chambers, 1994; Usadolo & Caldwell, 2016). Participants for the household survey were drawn using the systematic random sampling technique. The household survey assessed farmers observed trends of LUCC over time, household dependency on diverse provisioning ecosystem services for livelihood needs and the perceived effects of LUCC on a range of provisioning ecosystem services. The household survey also gathered data on farmers observation of the supply and availability of provisioning ecosystem services over a decade. A total of 206 (Adaboya = 102, Akanyoga/Beo = 104) and 194 (Nakong = 92, Kayoro = 102) household surveys were conducted in Bongo

Table 1. Accuracy assessment for Bongo and KNW districts (1990–2020).

LUCC	Bongo district						KNW district									
	1990		2000		2010		2020		1990		2000		2010		2020	
	P%	U%	P%	U%	P%	U%	P%	U%	P%	U%	P%	U%	P%	U%	P%	U%
Agriculture	77	73	60	76	86	80	90	90	69	88	89	82	80	93	93	85
Settlement	60	86	100	89	100	85	85	85	100	86	100	75	100	82	86	90
Bare Soil	61	81	30	15	80	85	65	86	75	75	62	87	69	100	89	80
Shrub and Tree Savannah	86	83	80	82	76	85	96	91	72	79	82	83	88	79	90	90
Water Body	100	100	96	96	100	100	100	95	100	100	91	100	100	100	100	100
Wooded Savannah	95	89	91	88	87	83	95	95	93	80	93	92	89	91	86	94
Overall accuracy	87		79		87		93		85		87		90		86	92

and KNW districts, respectively. In all, 400 households answered the questionnaire. All household interviews were conducted in vernacular, which were interpreted by linguistic experts acting as research assistants. Household surveys generally lasted for 50 min.

Two FGDs were conducted in each study community (four FGDs in each district) and one FGD each at the two selected district(s) level with officials from Government and NGOs. A total of 10 FGDs (five in each district) were conducted for this study. Based on suggestions in the literature concerning group sizes (Antwi-Agyei, 2012), a minimum of five to a maximum of 10 individual farmers were purposefully selected for the FGDs based on their extensive ecological knowledge noticed during the survey (Chambers, 1994; Usadolo & Caldwell, 2016). To guarantee a fair representation of farmers with distinct economic and social attributes, considerable attention was given to age, wealth status and gender in the selection of participants for the FGDs. Having noticed that cultural and social circumstances restricted women from expressing themselves especially in the presence of men, separate FGDs were organized for women farmers. This sought to resolve the often-cited dilemma of power relationship and how it affects decision-making processes at the local level (Chambers, 1994; Usadolo & Caldwell, 2016). The main themes discussed in the FGDs centred on LUCC trajectories, farmers dependency on ecosystems for livelihood needs, farmers perceived effects of LUCC on provisioning ecosystem services and landscape governance mechanisms employed by farmers at the local level. Generally, each FGD lasted one-and-a-half hour. FGDs were recorded in farmers native language and later translated and transcribed into English by linguistic experts. Individuals who were deemed knowledgeable on issues related to landscape and ecological change were specifically contacted for detailed key informant interviews.

One key informant interview was held in each of the study communities (four total) with local farmers and opinion leaders while four key informant interviews were held at the district (two in each district) with environmental experts working with Government and NGOs. Two key informant interviews were held at the regional level with officials of Ministry of Food and Agriculture (MoFA) and Environmental Protection Agency (EPA). A total of 10 key informant interviews were conducted. Key informant interviews covered themes on LUCC change trends and patterns and driving forces, the impact of changing land cover and land use dynamics on supply of provisioning ecosystem services and multi-scale governance mechanisms. The key informant interviews permitted extensive discussion of the most important issues highlighted in the FGDs and household survey. Key informant interviews were face-to-face and took one hour.

Oral narratives as a research method are much prominent in climate and geographical studies. Oral histories are often used by researchers to reflect on some past events and traditions (Antwi-Agyei, 2012). Oral histories were

conducted to provide insights into the historical actions, events and occurrences that have shaped the landscape trajectories and ecosystem services change thereof in the study areas. Information from historical narratives of landscape and ecosystem change were compared and corroborated with satellite images to depict the trends in LUCC for the two selected study districts. A total of four oral narratives were conducted (one each in the four selected communities).

3. Results

3.1. Satellite mapping compared to local perceptions of trends in LUCC in Bongo and KNW districts

Figures 3 and 4 illustrate the trends in LUCC in the study sites for the period 1990 to 2020. The satellite data revealed significant expansion of agriculture land. Cropland expanded from an initial 459.18 Ha (4.59 KM²) in 1990 to 17,862.48 Ha (178.63 KM²) of total area due to decreases in wooded savannah area, which declined from 176.022 KM² of total area to 29.22 KM² of total area from 1990 to 2020 in the Bongo district. The highest percentage change (8.16%) in agriculture land occurred between 1990 and 2000, while the highest percentage change (-14.91%) in wooded savannah area occurred between 2010 and 2020. In the KNW district, significant declines occurred in wooded savannah area from 471.685 KM² to 258.38 KM² (net loss of 213.31

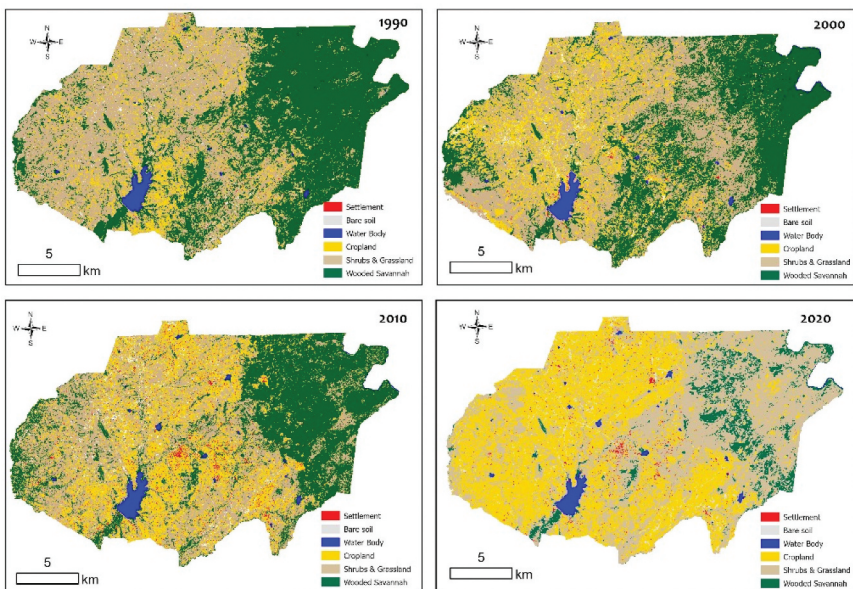


Figure 3. LUCC map of Bongo district (1990–2020).

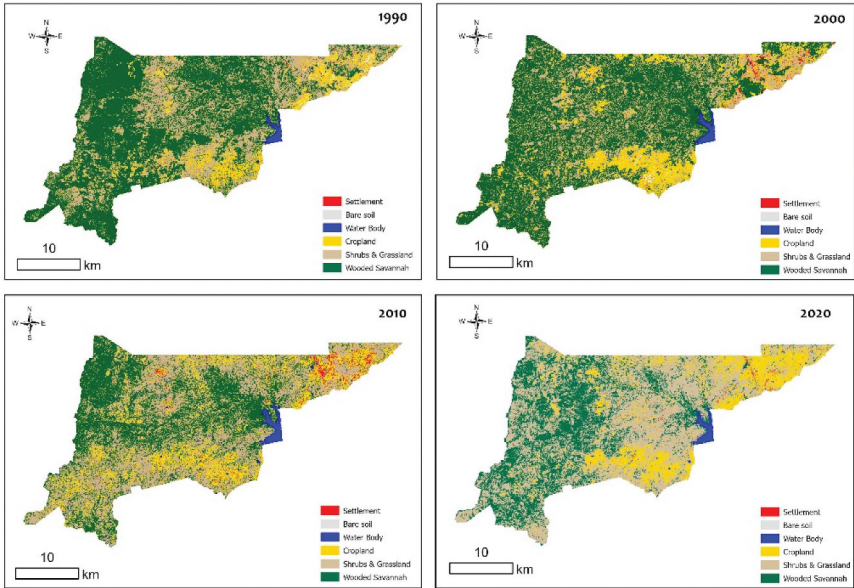


Figure 4. LUCC map of the KNW district (1990–2020).

KM²) of total area between 1990 and 2020 (Figure 4). Agricultural areas consistently increased from 1990 to 2020 (5.79 KM² to 123.80 KM²), however, the highest percentage increase (4.64%) was recorded from 1990 to 2000. Generally, farmers’ observation of historical LUCC dynamics mirrors the trends from the satellite data. A greater proportion (66.8%) of farmers believe that wooded savannah area has decreased between 1990 and 2020. Conversely, a higher proportion of farmers (56.5%) also attest to the visible expansion of agriculture area between 1990 and 2020.

Approximately, 19.5% of the farmers viewed agricultural lands to have remained the same, while 24% of farmers indicated that agriculture lands have rather decreased (Table 2). Farmers who indicated that agriculture lands have decreased may not have gotten it wrongly, since

Table 2. Farmers assessment of the trends in LUCC in Bongo and KNW districts, 1990 and 2020.

Indicator of change	LUCC types	Wooded savannah	Shrub & tree savannah	Agriculture land	Bare soil	Settlement	Water Bodies
Decrease	Bongo	29.5%	12.2%	14%	7.5%	12.2%	12.8%
	KNW	37.2%	7.8%	10%	15%	7.8%	4.5%
	Total	66.8%	20%	24%	22.5%	20%	17.2
No change	Bongo	12.8%	14.5%	11.2%	1.8%	14.5%	12.5%
	KNW	6%	14.8%	8.2%	19.5%	14.8%	16.2%
	Total	18.8%	29.2%	19.5%	21.2%	29.2%	28.7%
Increase	Bongo	9.2%	24.8%	26.2%	42.2%	24.8%	26.2%
	KNW	5.2%	26%	30.2%	14%	26%	27.8%
	Total	14.5%	50.7%	56.5%	56.2%	50.7%	54%

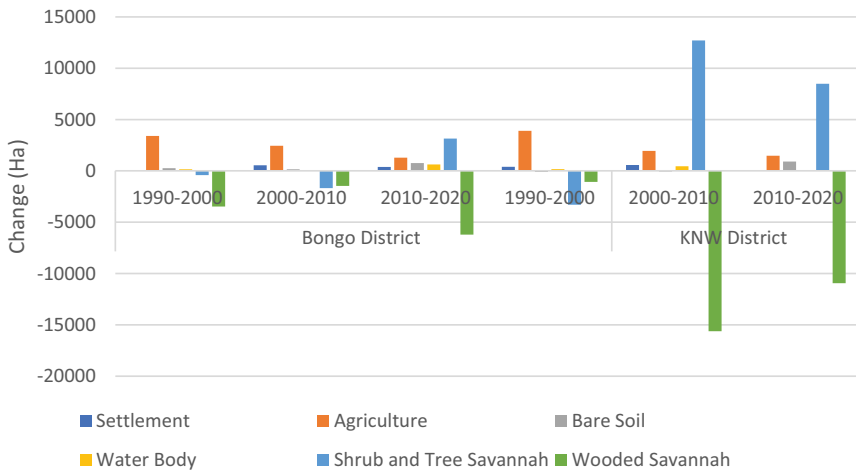


Figure 5. LUCC change for 1990–2020 in Bongo and KNW districts.

individual units per acreage of cropland have decreased. Due to population expansion, overall agriculture area in relation to total area has increased, but individual per unit acreage of land has decreased, especially in Bongo District. A key informant from the Beo community had this to say.

... land that was supposed to be mainly for agriculture has witnessed some roads cutting into them. Structures and buildings have also sprung up everywhere. So, at the moment we have more roads now as compared to some years back. Therefore, agricultural space is drastically reducing. (Key Informant Bongo district, 2020)

With regard to the other land use/cover forms, the satellite data show that the shrub and tree savannah area decreased from 191.075 KM² of total area to 170.099 KM² of total area from 1990 to 2010, then marginally increased to 201.808 KM² of total area by 2020 in the Bongo. Conversely, in the KNW district, shrub and tree savannah area decreased from 276.421 KM² of total area to 243.382 KM² of total area between 1990 and 2000. By the turn of 2020, shrub and tree savannah area expanded to 455.256 KM² of total area. The expansion of shrub and tree savannah area is due to the substantial declines in wooded savannah area. Bare soil consistently increased by a cumulative percentage of 3% between 1990 and 2020 in the Bongo districts (Figure 4). On the other hand, Bare soil area marginally decreased in the KNW from 1990 to 2010 by 0.20% but increased significantly by 1.081% (11.2167 KM²) of the total area by 2020 (Figure 5).

Table 3. Likert scale measurement of farmers dependence on major ecosystems for livelihood needs.

Major ecosystem	District: N=400	Not dependent (%)	Less dependent (%)	Moderately dependent (%)	Dependent (%)	Highly dependent (%)
Forest Ecosystem	Bongo	1.5	4.5	14.2	15	16.2
	KNW	0.2	1	6.8	4.8	35.8
	Total	1.8	5.5	21	19.8	52
Agriculture Ecosystem	Bongo	0	1	8	12.8	29.8
	KNW	0	0	1	9.2	38.2
	Total	0	1	9	22	68
Pasture/range Ecosystem	Bongo	4	10.8	19.2	13.8	3.8
	KNW	4.8	7.5	11	7.2	18
	Total	8.8	18.2	30.2	21	21.8
Water Ecosystem	Bongo	4.2	8	19.5	13.8	6
	KNW	0.2	1.2	5.8	8.5	32.8
	Total	4.5	9.2	25.2	22.2	38.8
Built-Up Ecosystem	Bongo	1.2	11.8	20	10.8	7.8
	KNW	0.5	7	15.5	12	13.5
	Total	1.8	18.8	35.5	22.8	21.2
Bare land Ecosystem	Bongo	17	10.2	17.2	5.5	1.5
	KNW	10.8	17	6.2	4.2	10.2
	Total	27.8	27.3	23.5	9.8	11.8

We confirm that perceptions of farmers were consistent with existing satellite data analysis although we could not statistically correlate the geospatial satellite data with the immeasurable information based on perceptions of farmers. The expansion of bare soil in the Bongo district as shown in the satellite data analysis has been confirmed by 42.1% of farmers in the Bongo district. A greater proportion (50.7%) of farmers have also observed the expansion in settlement area, while about 54% of farmers attest to the expansion of water bodies (Table 2).

A total of about 28.7% of farmers in both districts have seen no change in the total area of water bodies. Farmers who indicated no change in total area for water bodies may not be wrong, since some of the water sources (rivers, streams and dug outs) are perennial and usually dry out by the middle of the dry season (February to May). For instance, most of the mini dams constructed by the various irrigation initiatives of Government and NGOs usually dry out during the dry season and may not meet the water requirement of farmers, hence their assessment of decreasing trends in the total area of water bodies is apt. During an FGD, a discussant remarked that:

... during the rainy season, we usually have widespread availability of water because we have most of our water bodies been silted. However, in the dry season, most of the water bodies dry up due to the shallow nature of the water basins. To some extent water availability tend to be seasonal in recent times ... (FGD participant, Beo community, 2020).

3.2. Farmers dependency on ecosystems for livelihood needs

Farmers' assessment of their dependence on ecosystem services for their livelihoods and wellbeing is presented in Table 3. The proportion of households highly dependent (52%) on forest ecosystem is a little lower than the share (68%) of households who depend highly on agricultural ecosystem services for livelihood needs. More households in the KNW district (38.2%) highly depend on agricultural ecosystem than households (29.8%) in the Bongo districts.

With respect to range ecosystems, a higher proportion (18%) of households in the KNW district depends highly on it compared to the Bongo district (3.8%). Similarly, a greater proportion (32.8%) of households in the KNW district depends highly on freshwater ecosystem for their livelihood needs compared to households (6%) in the Bongo district. In support of the foregoing trend of households' dependency on ecosystems, an opinion leader in Nakong community reiterated that.

... Since time immemorial we have always solely depended on these ecosystem areas ... the forest, land, and water for subsistence. We depend on these vital areas for herbs, fruits, food, game, and cooking fuel among many others. Although our dependency on trees for fuel and building wood have reduced, we depend solely on the water sources for aquatic life, construction of houses, and household use such as cooking and drinking. We also very much depend on forest and agriculture areas for livelihood sustenance, without which we cannot survive without external support ... (Key Informant Interview, Nakong in KNW, 2020)

3.3. Perceived effects of LUC on provisioning ecosystem services (supply and availability)

Table 4 presents the range of ecosystem services provided by the identified ecosystems and farmers' assessment of their status (supply and availability) over a period of 10 years. A significant proportion of households (45.2%) perceived increasing trends in cereals/grains availability in both study districts around the year 2010. However, by 2020, the percentage of households witnessing decreasing trends rose from 14.5% to 46.8%. A community leader in the Adaboya community gave account of the following living testimony:

... For some time now, there has been a great decline in the quantity or output of cereals per the yearly harvest. About 10 years ago, we could obtain up to five of the 50 kg bags of maize on an acre of land but this time around, when we cultivate on the same parcel of land, we sometimes do not even get up to two bags. My silos used to get full after harvest with excess remaining. But these days it scarcely even gets up to half of the storage facility despite the extra hands and hard work we devote to the farming activities ... (Key informant, Adaboya, 2020)

Table 4. Perceived effects of LUCC on provisioning ecosystem services.

Provisioning Ecosystem services	Districts: N=400	Decrease Greatly (%)	Decrease (%)	Stay the same (%)	Increase (%)	Increase Greatly (%)
Cereals/Grains-2010	Bongo	0	10.8	17.8	21.2	1.8
	KNW	0.5	3.8	11.8	24	8.5
	Total	0.5	14.5	29.5	45.2	10.2
Cereals/Grains-2020	Bongo	18.8	22.5	6	4	0.2
	KNW	7.5	24.2	9	6.8	1
	Total	26.2	46.8	15	10.8	1.2
Fuelwood-2010	Bongo	0.5	4	30.8	15.2	1
	KNW	0.5	0.8	29.2	16.2	1.8
	Total	1	4.8	60	31.5	2.8
Fuelwood-2020	Bongo	17.5	22.2	11.2	0	0.5
	KNW	1.8	17	25.5	3.2	1
	Total	19.2	39.2	36.8	3.2	1.5
Fodder/forage-2010	Bongo	1	6.8	33	10.5	0.2
	KNW	0.2	3	24.2	18.8	2.2
	Total	1.2	9.8	57.2	29.3	2.4
Fodder/forage-2020	Bongo	9.2	17.2	23.5	1.5	0
	KNW	1.5	19.5	23.5	3.5	0.5
	Total	10.8	36.8	47	5	0.5
Grazing Fields-2010	Bongo	0.8	6.2	28.2	15.1	1
	KNW	0.5	0.8	28.5	15.2	3.5
	Total	1.2	7	56.8	30.5	4.5
Grazing Fields-2020	Bongo	20.2	20.5	10.2	0.5	0
	KNW	20.2	3	23.5	1.8	0
	Total	40.4	23.5	33.7	2.3	0
Medicinal Plants-2010	Bongo	6	0.5	30.8	12.2	2
	KNW	1	0	24.5	15.5	7.2
	Total	7	0.5	55.2	27.8	9.5
Medicinal Plants –2020	Bongo	15.2	16.8	19	0.5	0
	KNW	15.8	6.2	24.2	2	0.2
	Total	31	23	43.2	2.5	0.2
Wild edible fruits and vegetables –2010	Bongo	0.8	3.8	27	18.5	1.5
	KNW	0	1.5	26	14.8	6.2
	Total	0.8	5.2	53	33.2	7.8
Wild edible fruits and vegetables –2020	Bongo	10	21.2	20	0.2	0
	KNW	4	16.2	25.2	3	0
	Total	14	37.5	45.2	3.2	0
Game-2010	Bongo	1.2	6.5	28	14.8	1.2
	KNW	0.5	0.2	26.5	17.5	3.8
	Total	1.8	6.5	54.5	32.2	5
Game –2020	Bongo	20.5	19.8	10.5	0.8	0
	KNW	7.2	15	24.5	1.2	0.5
	Total	27.8	34.8	35	2	0.5
Building Materials-2010	Bongo	0	4.8	33.2	13.2	0.2
	KNW	0.2	2	29	13.2	4
	Total	0.2	6.8	62.3	26.5	4.2
Building Materials –2020	Bongo	10	24.8	16.8	0	0
	KNW	3.5	16	26.5	2.2	0.2
	Total	13	40.8	43.2	2.2	0.2
Fish-2010	Bongo	1	5.5	30.8	12.8	1.5
	KNW	1.5	1	25.2	16.2	4.5
	Total	2.5	6.5	56	29	6
Fish –2020	Bongo	14.2	14.2	21.2	1.2	0.5
	KNW	4.5	15.5	17.8	7.2	3.5
	Total	18.8	29.8	39	8.5	4

Generally, the supply of fuelwood was more stable around the year 2010 (60%) compared to 2020 (36.8%) per the research findings on the perceived effects. A similar trend is observed for fodder/forage. A total of 57.2% of households perceived that there was a stable supply of fodder/forage as of 2010. However, the percentage of households witnessing decreasing trends for fodder/forage rose from 9.8% in 2010 to 36.8% by 2020. A total of 56.8% of households in both districts reported a stable supply of grazing fields in the year 2010. By the turn of 2020, although 33.7% of households in both districts perceive the supply of grazing fields to be stable, about 23.5% and 40.4% of households in both study districts perceive the supply of grazing fields to decrease and decrease greatly, respectively. Decreasing trends in supply of grazing fields were more pronounced in Bongo District (20.5%) than KNW District (3%).

The availability of medicinal plants was more stable (55.2%) around the 2010 period. However, the number of households perceiving decreases in medicinal plants availability rose from a total of 7% in 2010 to 31% in 2020. More households in Bongo District (16.8%) perceive decreasing trends in availability of medicinal plants than households in the KNW District (6.2%). With regard to wild edible fruits and vegetables, the total proportion of households perceiving decreasing trends in their availability shot up from 5.2% in 2010 to 37.5% in 2020. Nonetheless, a lot of households in Bongo District (21%) than KNW District (16.2%) are witnessing decreasing trends of wild edible fruits and vegetables availability by 2020. The total proportion of households who perceive decreasing trends in the availability of game rose from 6.5% to 34.8% between 2010 and 2020, respectively. The decreasing trends are more pronounced in Bongo District (20.5%) than KNW District (7.2%). The proportion of households in both Bongo and KNW Districts that perceive decreasing trends in the availability of building materials rose from 6.5% in 2010 to 40.8% in 2020. In Bongo District, the proportion of households that perceive decreasing availability of building materials rose from 4.8% in 2010 to 24.8% in 2020, comparatively higher than the proportion of households in KNW District, which rose from 2% in 2010 to 16% in 2020. A key informant at the Adaboya community shed light on the evolving trends:

... Generally, the changes in land use and cover in recent years has negatively affected the supply of services we derive from the environment. Access to building materials like wood and grasses is difficult to get even in the forest. Access to firewood and edible wild fruit is also difficult to get resulting from the same reason of excessive tree cutting. The soil has also lost its fertility probably due to the burning of crop residue and continuous cropping leading to a reduction in the yields of grains and vegetables. Wild animals were very common in this community, even in our homes we could see animals like rats and rabbits. Hunting was a lucrative business in those days, but now hardly will you see a wild animal in the forest and most hunters are out of business ... (Key informant interview, Adaboya, 2020)

Increasing trends in water bodies in both study districts have not culminated in increases in the services (such as fish) obtained from freshwater ecosystems. The percentage of households in both districts who perceive decreasing availability and supply of fish rose from 6.5% in 2010 to 29.8% in 2020. Generally, the availability of all the nine provisioning ecosystem services identified in Bongo and KNW Districts were more stable as of 2010. The supply of some services increased marginally, especially in the wet or rainy season, as of 2010. However, by the turn of 2020, the highest proportion of households perceive significant decreases in the supply and availability of most of the provisioning ecosystem services. In response to the gradual decreases in the supply of vital provisioning ecosystem services over the years, the Government of Ghana, and its agencies such as the EPA, forest commission and MoFA has recognized the importance of nature conservation for future generations and consequently taken various actions that promote sustainable landscape governance. An official of EPA in account of government efforts towards sustainable landscape governance remarked that:

The phenomenon of decreasing ecosystem services has been widespread in savannah zone for some time now ... at least the past 2 decades, but current depletion levels are unprecedented. The EPA, Forest Commission in collaboration with other agencies have over the years promoted natural resource conservation. EPA led the implementation of the National Biodiversity Strategy and Action Plan with the goal of conserving biodiversity and promoting sustainable use of resources in agriculture, forestry, and wetlands. About a decade ago we (Government agencies) began executing activities on the Reducing Emissions from Deforestation and Forest Degradation (REDD+) with the aim of conserving forest ecosystems for livelihood needs. Within the last 5 to 10 years the National Climate Change policy of Ghana and the Paris agreement which Ghana is a signatory, contain strategies that aim to reduce vulnerability to decreasing ecosystem services and promote sustainable livelihoods ... (Key informant interview, Regional EPA, 2020)

4. Discussion

The historical narratives reported by farmers and the geospatial remote sensing data yielded similar results, which enhances our confidence in both methods. The pros of employing the geospatial approach lie in its quantitative nature, spatial completeness and objectivity. Nevertheless, the geospatial remote sensing approach is inept in providing detail information on why the changes occurred and can contain some sources of error (e.g cloud cover) (Ewunetu et al., 2021; Senbeta, 2018). On the contrary, the qualitative narratives from local actors provided in-depth intuitions of the underlying driving forces of LUCC which cannot be discovered using the geospatial analysis alone (Ewunetu et al., 2021). For instance, local actor interviews with experts revealed that colonial forest reservation policies, economic opportunities in

and outside of the study areas and biological constraints are the key variables that drive LUCC in the Bongo and KNW districts. Given the resemblance of the results, it implies that the limited geospatial remote sensing approach when triangulated with qualitative interviews from local actors and farmers enhances the accuracy of the results.

Generally, the results suggest that expansion in agriculture area has been driven by increases in cultivated area and rapid population growth which require the clearing of uncultivated land to start new farms, resulting in significant deforestation of woodlands and natural ecosystems (Yiran et al., 2012). Similarly, bad farming practices, wood harvesting and logging, charcoal production, and mining activities which constitute key livelihood portfolios for the rural people are significant drivers of decreasing woodland areas. Expansion in settlement areas and bare soil have been visible in the study areas. The most obvious causes of expansion in settlement area include rapid population growth, economic development, and infrastructure development (Kleemann et al., 2017). The widespread expansion in agriculture area, settlement, and bare soil and shrub and tree savannah area are the key drivers of the declines in woodlands. Wooded savannah area is the dominant habitat for most of the natural ecosystems and important species (Wardell et al., 2003). The savannah ecological zone of Ghana has been witnessing major LUCC in recent years (Aniah et al., 2023) and the results of our study also validate these claims, with the depiction of net reduction in wooded savannah area by 63.31% and 58.591% of total area between 1990 and 2020 in the Bongo and KNW districts, respectively. Expansion of agriculture area degrades half of the natural ecosystem, posing significant threat to biodiversity and diminishes the natural capacity of the landscape to maintain ecosystem and biodiversity functions such as supply of ecosystem services (Karki et al., 2018). Government and development partners have responded to these circumstances by initiating interventions such as tree planting and agroforestry, though the survival rate is very low due to intermittent drought, livestock grazing, fire outbreaks and inadequate care.

People living in rural areas depend largely on provisioning ecosystem services for their livelihood and well-being. Provisioning ecosystem services are vital economic and ecological resources and benefits that humans derive from the natural ecosystem (Chaudhary et al., 2016; Karki et al., 2018). Provisioning ecosystem services are relevant to the inhabitants of the savannah ecological zone who have limited livelihood options and largely depend on physical and natural ecosystems for a living. Although the dependency on ecosystem services varies based on proximity (Karki et al., 2018), households in the study areas are predominantly dependent on agriculture, forestry, and freshwater ecosystems. These three major ecosystems are the leading ecosystems that inhabitants rely greatly on for their livelihood requirement. These ecosystems provide diverse wild foods and medicines, energy and

fuelwood, timber and non-timber products, ecological services including biodiversity conservation and water supply. These wide range of ecosystem services can only be supplied continuously if the natural ecosystem is maintained and resilient against external perturbations. A harmonized human-nature interaction is vital for maintaining a resilient ecosystem. The prevailing LUC dynamics noticed in the study areas is evident of the weakening capacity of the major ecosystems in meeting the livelihood needs of inhabitants. The deteriorating major ecosystem, which is still expected to provide households with a means of livelihood, is one of the fundamental causes of the irreversible damages caused to the natural ecosystems, resulting in continuous poverty, food and livelihood insecurity and curtailed development in the savannah ecological zone of Ghana (Alhassan, 2020, 2015; Kumasi et al., 2019). Since access to provisioning ecosystem services is shaped by land tenure arrangements, men have more access than women because land ownership rights tend to favour men more than women.

Assessing smallholder farmers perceived effects of LUC allows for an understanding of how the quantity and quality of provisioning ecosystem services are altered by anthropogenic activities. Such assessments at the local level are relevant in guiding appropriate policies to enhance ecosystem resilience and sustainable development since smallholder farmer livelihoods and ecological processes are hampered by adverse LUC (MEA, 2005). These assessments can inform local-level land management decisions which are beneficial for both the environment and farmers, promote local participation and potentially increase the success rate of conservation efforts (MA, 2005; Aretano et al., 2013; Hasan et al., 2020; Yang et al., 2019). Forest area in the savannah ecological zone has been facing severe degradation due to the changing land use dynamics and land cover over the past few decades (Koo et al., 2018). There have been substantial decreases in woodlands and forest areas globally rendering it a question of global concern (Aretano et al., 2013; Yang et al., 2019). Although agriculture land is indicated to have increased in total area, individual per unit acreage of land has not increased due to high population density in the study districts. The expansion in agriculture land have not resulted in corresponding increases in yields of cultivated crops due to severe degradation and loss of soil fertility. As a result of the loss of soil fertility and the consequential declines in yields, there is currently growing use of agrochemicals which have fostered the gradual disappearance of many pollinators, and the absence of pollinators have contributed to the continuous declines in yields of rice, millet and maize, and vital economic trees such as shea and dawadawa trees in the study area (Stein et al., 2017; Van Asselt et al., 2018). Local people reiterated that the quality and quantity of critical provisioning ecosystem services such as wild edible fruits and vegetables, medicinal plants, fish, game, animal fodder/forage, fuelwood and building materials have declined considerable over the past decade (Boafo et al., 2014,

2016). The Millennium Ecosystem Assessment (MEA) found that more than half of the world's provisioning ecosystem services have deteriorated (MA, 2005). LUCC is responsible for about 60% of the degradation of provisioning ecosystem services (Aretano et al., 2013; Yang et al., 2019). Growth of the human population increases demand for natural resources and the production of more food to feed the needs of human populations (Hasan et al., 2020; Yang et al., 2019), putting extreme pressure on the major ecosystems, and the resultant decreases in the services provided by these ecosystems (Hasan et al., 2020). The perceptions of farmers and detected trends (using satellite data) in the savannah ecological zone are in tandem with observations of other studies (Aretano et al., 2013; Rimal et al., 2019; Yang et al., 2019). The degradation of vital provisioning ecosystem services (a consequence of LUCC) is the root cause of livelihood insecurity, chronic poverty, and malnutrition, and this consequentially reduces human wellbeing in savannah ecological zone (Alhassan, 2020; Kumasi et al., 2019). The development of policies on landscape governance and biodiversity conservation to safeguard ecosystems, their accompanying services and livelihoods needs although are important, but should be grounded on accurate assessment of ecosystems at the local level using a blend of geospatial and primary information. Ghana's current landscape governance mechanisms (such as the national climate change policy, national REDD+ strategy, National Biodiversity Strategy and Action Plan) fail to adequately involve marginal groups such as smallholder farmers. The government and NGOs adaptation plans have also been implemented as standalone and are not integrated into wider development priorities missing the possibility of co-benefits across different sectors. A much-desired landscape governance mechanisms should ideally consider long-term risks rather than short-term solutions by prioritizing resilience building (nature regeneration) instead of adaptation to ecological change.

The ESC adopted in this study has enabled the assessment of the impacts of LUCC on provisioning ecosystem services. Since social and ecological systems are dynamic, alterations in social systems (population growth, increasing demand for resources, economic incentives, etc.) will invariably result in changes in the ecological systems (land use change, land cover change, changing ecosystem services) (Rugani et al., 2019). The linearity of the ESC oversimplifies the complexity underlying the ecosystem functioning (step 1 and step 2) and the interrelations with human well-being (step 4). The ESC should be made more integrative and non-linearized so that the multifaceted connection between ecological systems and the social systems can be assessed more holistically. To establish a real cause-effect chain in ESC, it is beneficial to integrate the ESC with the Drivers, Pressure, State, Impacts and Response (DPSIR) framework (see Gerner et al., 2018; Gomes, 2020; Nassl & Löffler, 2015). The drivers, generated in the social system, proximately or indirectly cause LUCC and changes in governance strategies. The LUCC is

the apparent link between the ecological and social system and denotes the pressure exerted by humans on the ecosystem. The pressure exerted by the social system results in modifications in the state of the ecosystem (natural ecosystem-Step 1). The modifications to the natural ecosystem will impact on ecosystem function (step 2) and ecosystem services (step 3) and benefits (step 4). Impacts on the ecosystem services and benefits will result in social impacts with consequential influences on perceived impacts on ecosystem service values (step 5). The social impacts can also modify the drivers of LUCC and governance mechanisms. National, regional, and local-level responses can be implemented due to the modifications to the state of the ecosystem that result in diverse social and ecological impacts. The responses can influence the changes in the drivers that exerts pressure on the ecosystem leading to a cyclical modification of the social and ecological system and provision of diverse tangible and intangible ecosystem services. The integration of ESC and DPSIR frameworks will create harmony between social and ecological systems, bridge science and policy and solve the often-cited limitation of the ESC as being linear and oversimplification of complex ecological functioning.

5. Conclusion

Ecosystems provide numerous services in diverse quality and quantity but are currently threatened by changing land use and cover. The significance of provisioning ecosystem services to the livelihood requirement of local communities in developing countries has been recognized by the IPBES. This study has brought to light that LUCC is occurring and has implications for sustainable supply and availability of provisioning ecosystem services required for human livelihoods. The geospatial analysis of the dynamics of LUCC in both Bongo and KNW Districts has shown that agriculture and settlement areas increased while wooded savannah area decreased in the last three decades. In sync with observations from the satellite data, farmers generally perceive expansion in agricultural areas at the expense of wooded savannah areas even though farmers in both study districts depend highly on most of the ecosystems for their livelihood needs. The substantial changes in land use and cover over time have weakened the capacity of the ecosystems to continually provide vital services for livelihood needs. The decreases in the capacity of the ecosystems to provide services have resulted in significant declines in key provisioning ecosystem services. Farmers in both study districts perceive the supply and availability of provisioning ecosystem services such as wild edible fruits and vegetables, building materials, fish, game, and medicinal plants to have decreased greatly over the past decade. The decline in the supply and availability of provisioning ecosystem services has increased livelihood insecurity and wellbeing of the inhabitants has deteriorated. The need to initiate or revamp sustainable environmental and

agronomic practices such as reclamation of degraded lands, natural regeneration and agroforestry by state agencies, civil society organisations, donor groups, and affected farmers could not have been more pressing since they will enhance ecosystem services resilience, by extension enhancement of farmers' livelihoods.

Ethical issues

The protocols for this study were approved by the University of Ghana, College of humanities ethical review board (Ethical approval No: ECH 011/20–21).

Disclosure statement

No potential conflict of interest was reported by the author(s).

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