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Land use land cover dynamics and its implications for ecosystem services and livelihoods of Budongo forest adjacent communities

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Abstract

A deeper understanding of land use land cover (LULC) dynamics is essential for the sustainable management of the environment and its natural resources, and importantly how the changes affect the provision of ecosystem services and community livelihoods. This study examined the spatio-temporal LULC dynamics around the Budongo Central Forest from 1995 to 2022 and the implications these changes have on the provision of ecosystem services and the livelihoods of local communities. Data were collected using a hybrid approach involving satellite image classification, post-classification change detection, interviews with 156 respondents and 17 key informants. Survey data were subjected to descriptive statistics, Mann-Whitney U tests and Ordinary Least Squares (OLS) regressions. The study results reveal a decline in areas covered by wetlands, forests and grasslands due to the expansion of commercial sugarcane plantations, compounded by an increase in the population emanating from migrant workers. While the area under subsistence agriculture had a marginal expansion, local communities perceived that the changes in LULC resulted in a decline in households' food availability, water availability and soil fertility. The study concludes that changes in LULC are associated with significant losses in natural assets and ecosystems. These loses in natural assets have significant effects on the livelihoods of community members. Therefore, there is a need for instituting a participatory land use planning approach in the affected communities to mitigate the effects of the LULC changes. This will also help in fostering sustainable natural resource management within the affected communities.

1. Introduction

Land remains a critical natural asset that supports human development globally and the way it is used and managed impacts livelihoods and the achievement of sustainable development. However, as human population growth continues to drive demand for land, anthropogenic activities such as agriculture, human settlements and urbanization, mining and deforestation continue to change land uses and land covers globally, regionally and locally (Mei *et al* 2016, Munthali *et al* 2020). Land users with different socio-economic statuses and power compete to achieve the benefits of land use such as food security, economic growth, energy supply, biodiversity conservation, and other objectives amidst such competition (Für 2011). Furthermore, competition for land amongst different uses occurs alongside growing demand for land from alternative activities such as urbanization, outdoor recreation, mining, food production and biodiversity conservation (Metternicht 2017).

In tropical Africa, growth in the human population has increased the demand for land for subsistence and commercial use. The populations living around forests have equally increased over the recent past, thereby causing forest degradation and regression (Aubréville 2023) which is also associated with proximity to human settlement (Lhoest *et al* 2020). Over time, land-use changes resulting from expansion of agricultural activities and settlements reduce land productivity through loss of soil nutrients and organic matter (Xu *et al* 2020). In Uganda, land constitutes the main capital asset available to the population and accounts for 54% of the country's total assets. It is mainly used for crop production, pasture lands, protected areas, forests and wetlands (Twinomuhangi *et al* 2015). The LULC changes often result in a decline in the forest cover, biodiversity loss and to land degradation (Kizza *et al* 2016, Banadda 2019), all of which pose serious environmental and socio-economic impacts for rural livelihoods that are largely dependent on natural resources (Twongyirwe *et al* 2015). For the subsistence farming communities and households that live around forests, changes in LULC have implications for the provision of ecosystem services and sustaining livelihood and well-being. Furthermore, commercial agriculture is increasingly replacing subsistence farming because of quick commercial gains (Mwavu *et al* 2018). Market-driven land use patterns kindle unsustainable land use and cause irreversible loss of biodiversity and soil fertility (Erdoğan *et al* 2013). This is common around tropical forests where unique biodiversity has continuously been threatened by human activity through habitat destruction and defaunation (Lhoest *et al* 2020). Such effects on communities could either be positive or negative, and the consequences of these effects may be intended or unintended (Hansen and DeFries 2004, Munthali *et al* 2020). Despite affecting ecosystem services and community livelihoods, a few studies have examined the effects of LULC changes from a livelihood perspective in Uganda (Luwa *et al* 2020). Studies done in this context (Twongyirwe *et al* 2015, Majaliwa *et al* 2018) focused on the effects of land use and land cover on natural resource conservation.

The absence of an integrated analysis of the effects of LULC changes in the above studies reveals a gap that this study strives to fill. Limited research on LULC dynamics, including analysis of current land cover changes and their implications for local communities' livelihoods, presents a fundamental challenge to development planning that integrates forest conservation. Monitoring changes in human activity around forest biodiversity hotspots is equally paramount for sustained ecosystem service provision. Budongo forest managers and communities need to make evidence-based decisions to achieve a balance between LULC changes, forest conservation and local communities' livelihoods. This study examined the LULC dynamics around the Budongo Central Forest and documented evidence that changes in LULC have significant effects on ecosystem services and livelihoods of adjacent communities. This study contributes to the existing debates on land use land cover change and its implications on ecosystem services and livelihoods of communities.

2. Materials and methods

2.1. Study area

Tropical forests such as Budongo are increasingly facing negative impacts of human activities that are impairing their health and the provision of ecosystem functions and services (Lewis *et al* 2015). Budongo Central Forest Reserve is located between 1°37 N–2°03 N and 31° 22–31°46 E and 435 km^2 (figure 1) is a medium altitude moist, semi-deciduous tropical rain forest found at the top of the Albertine Rift (FAO 2013). The mean annual rainfall is 1,150–1,500 mm and the mean daily temperature ranges from 17 °C to 20 °C in the wet season and 28 °C to 29 °C in the dry season (BCFS 2016, World Weather Online 2020).

2.2. Data types, sources and processing

2.1.1. Remote sensing data acquisition and processing

Landsat satellite images were classified and integrated with change detection to determine LULC dynamics (Kuule *et al* 2022). Remote sensing data from the Landsat satellites were processed into maps using standard remote sensing techniques (Majaliwa *et al* 2018, Agarwal *et al* 2020) in ArcGIS 10.8.2 followed by ground-truthing (Mwavu *et al* 2018). To determine LULC change dynamics, Landsat satellite imagery of 1995, 2004, 2013, and 2022 corresponding to Path 172 and Row 059 were downloaded from the United States Geological Survey (USGS) Earth Explorer website https://earthexplorer.usgs.gov/. Landsat images were selected bearing in mind the years, quality, time of the year and cloud cover. All images were of a 30 m spatial resolution to enable spatial comparison and quantification. A baseline year (1995) was selected because Uganda's National Environmental Act came into force that year. Individual bands were combined into a single multispectral image (Boakye *et al* 2008). The images were classified using supervised classification techniques with a five-kilometer buffer for the selected villages. Maximum likelihood approach was used because it assumes a normal distribution and the pixels are composed of a single land cover/land-use type (Boakye *et al* 2008). This process generated five spectral classes that also represented land use and land cover types (based on the National Forestry Authority's National Biomass Study (NBS) classification system) deployed for change detection (table 1).

2.2.2. Accuracy assessment

Ground-truthing was undertaken with 256 training samples to confirm the validity of land use land cover classes while accuracy was determined by the reliability of the classification. Kappa coefficient was computed to determine the validity and reliability of the Landsat images. User and producer accuracies of the classified images were determined together with

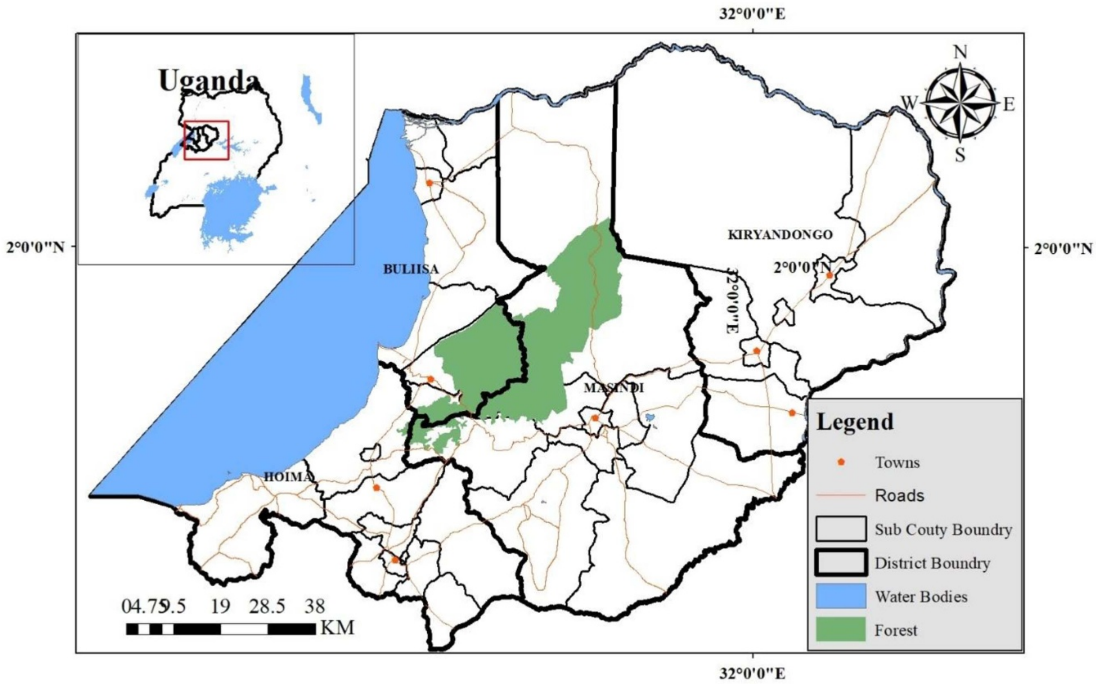

Figure 1. Map of the study area

Table 1. Description of land use and cover classes in the study area.

LULC Class	Description
Built-up areas	Permanent and semi-permanent buildings housing people and other infrastructure such as roads, factories, and buildings in towns or trading centres.
Forest	Areas of dense tree canopy comprising trees > 2 meters high (Kuule *et al* 2022).
Subsistence agriculture	Land cultivated for subsistence presented in one class due to the strong similarities in spectral reflectance of the different crops grown (Belayneh and Eyasu 2021).
Sugarcane	Land consisting of fields planted with sugarcane, previously cleared and awaiting regrowth of sugarcane and the crop in young stages (Mwavu *et al* 2018). Sugarcane growing in the study area is exponentially expanding in coverage (Kusiima *et al* 2022) thereby threatening the livelihoods of local communities.
Wetlands & Grasslands	Areas that are permanently or seasonally waterlogged comprising woody, herbaceous vegetation and areas where the vegetation is dominated by grasses (FAO 2013). Due to high similarities in reflectance that make it difficult to precisely differentiate between wetlands and grasslands in the study area, these two classes were merged.

Kappa coefficients after image classification and analysis based on the following equations:

$$\text{Overall Accuracy} = \frac{\sum_{i=1}^{r} xii}{x}. \quad (1)$$

Where x_{ii} is the diagonal element in the error matrix, x is the total number of samples in the error matrix.

Kappa coefficient

$$\text{K} = \frac{n\sum_{i=1}^{r} xii - \sum_{i=1}^{r} xi + x + i}{n\hat{}2 - \sum_{i=1}^{r} xi + x + i}. \quad (2)$$

Where $\boldsymbol{r}$ is the number of rows in the matrix,

x_{ii} is the number of observations in row i and column i,

xi and x_{+i} are marginal totals for row i and column i respectively and,

n is the total number of observations (pixels).

With the above equations, an error matrix of land use land cover changes between 1995 and 2020 was generated and overall accuracy and Kappa coefficient calculated. Image classification accuracy ranged from 0.857 to 0.961 (table 2) thus affirming that the classified images were suitable for the assessment of LULC changes. The suitability of the images was further manifested by the high kappa statistic values that ranged from 0.852 to 0.95. The respective confusion matrices for 1995, 2004, 2013, and 2022 were also calculated (table 2).

Spatio-temporal changes in the different LULC types over the years were captured through post-classification change detection of the four images

Table 2. Accuracy of the classified images.

Year	Overall accuracy	Kappa coefficient
1995	0.961	0.951
2004	0.953	0.941
2013	0.857	0.852
2022	0.961	0.951

(Sallaba 2009). A change matrix was used to compute the temporal changes between 1995–2004, 2004–2013 and 2013–2022 (Abuelaish and Olmedo 2016). This process helped to ascertain the changes in land use and land cover as well as the drivers and transition matrices over the period under study (Anwar *et al* 2022). With the above processes completed, the spatial and temporal changes in LULC were detected (Cheruto *et al* 2016).

2.2.3. Cross sectional survey data sources and analysis
LULC change data were triangulated and complemented with data from a cross-sectional survey of 156 household respondents to deepen our understanding of the LULC dynamics (Desalegn *et al* 2014). The survey was conducted between the months of June and August 2022. The respondents were randomly selected from households targeting the head or at least one adult growing sugarcane or who has lived in the study area for more than 10 years but not necessarily growing sugarcane. The questionnaire captured information on socio-economic and demographic characteristics of the respondents, current land-use practices (Desalegn *et al* 2014), and perceptions of LULC change impacts on livelihoods and ecosystem services. The communities were purposely selected because of the extensive changes in land use and land cover revealed by the image classification for the same area and their proximity to the forest reserve. The sample size for the respondents was determined using Yamane's formula (Oribhabor and Anyanwu 2019) expressed as:

$$n = N/\left[1 + N\left(e\right)2\right]. \tag{3}$$

Where:
n = sample size,
N = finite population,
e = error margin and,
1 = constant.

Data from the respondents were analysed with descriptive statistics and Mann–Whitney U tests to compare perceptions of respondents living in the town with those in the country side. We used Mann–Whitney U test to understand whether there were differences in the perceived effects of LULC changes between the respondents staying in Kabango Town Council (KTC) and those who stayed in Budongo Sub County (BSC). To interrogate the data beyond respondents' settlement patterns, OLS regression analysis was used to understand the effect of respondents' socio-demographic characteristics on their perception of LULC change implications on livelihoods and ecosystem services (Bazdaric *et al* 2021). The perceived effect of LULC changes on different livelihoods and ecosystem services proxy indicators including settlement patterns, soil fertility, social network and cohesion, water availability, food security, land available for food production, livestock production, natural capital assets, human-wildlife conflicts, human-human conflicts, and access to land were used as dependent variables (Kanyongo *et al* 2006). These variables were assessed on a four-point Likert scale of zero (0) to three (3) representing severity of the perceived effect of LULC change on the livelihood and ecosystem services parameter. Due to the non-normal distribution of the dependent variables, log transformations were conducted before subjecting them to OLS modelling (Burton 2021). The study also obtained data from 17 Key Informant Interviews (KIIs) purposively selected and interviewed (Nyumba *et al* 2018) with focus on knowledge of LULC change drivers (Kuule *et al* 2022). These Key Informants included environmental officers, conservationists, political leaders, and local community leaders. Out of these, nine were more than 60 years old in order to benefit from their hindsite knowledge of LULC changes over the past three decades in the areas around Budongo Forest Reserve.

3. Results

3.1. Respondents' profile

The majority (60.3%) of the respondents were male, which is not surprising given that the study area is mainly dominated by a patriarchal social order and the study targeted land ownership and decision-making on how households should use their land. The average age of the respondents was 41 years, the youngest was 18 and the oldest was 80 years. Most (84%) of the respondents were married, 9% were single, 3% were divorced and 4% were widowed (table 3).

The minimum land size owned by a household was 0.25 hectares while the maximum was 280 hectares (mean = 6.1 and standard deviation = 22.8). Majority (64.1%) of the household heads were male (table 3). Ninety four percent of the respondents had no education, while 50.6% had primary education.

3.2. LULC dynamics of Budongo forest reserve surrounding landscapes

The study assessed LULC dynamics of the Budongo Forest Reserve (BFR) surrounding landscapes for the years 1995, 2004, 2013 and 2022. LULC types around the BFR for the period between 1995 and 2022 included built-up areas, forest, subsistence agriculture, sugarcane plantations, wetlands and grasslands (figure 2).

Table 3. Characteristics of respondents.

Parameter	Category		Frequency (%)	
Sex	Female		62 (39.7)	
	Male		94 (60.3)	
Marital status	Single		14 (9.0)	
	Married		131 (84.0)	
	Divorced		4 (2.6)	
	Widowed		7 (4.5)	
Position of respondent in household	House Hold Head		100 (64.1)	
	Spouse		47 (30.1)	
	Others		9 (5.8)	
Education	None		32 (20.5)	
	Primary		79 (50.6)	
	Secondary		35 (22.4)	
	College		8 (5.1)	
	University		2 (1.3)	
	Mean	Std. dev.	Min	Max
Age	41.1	14.4	18	80
Land size owned	6.1	22.8	0.25 ha	280 ha

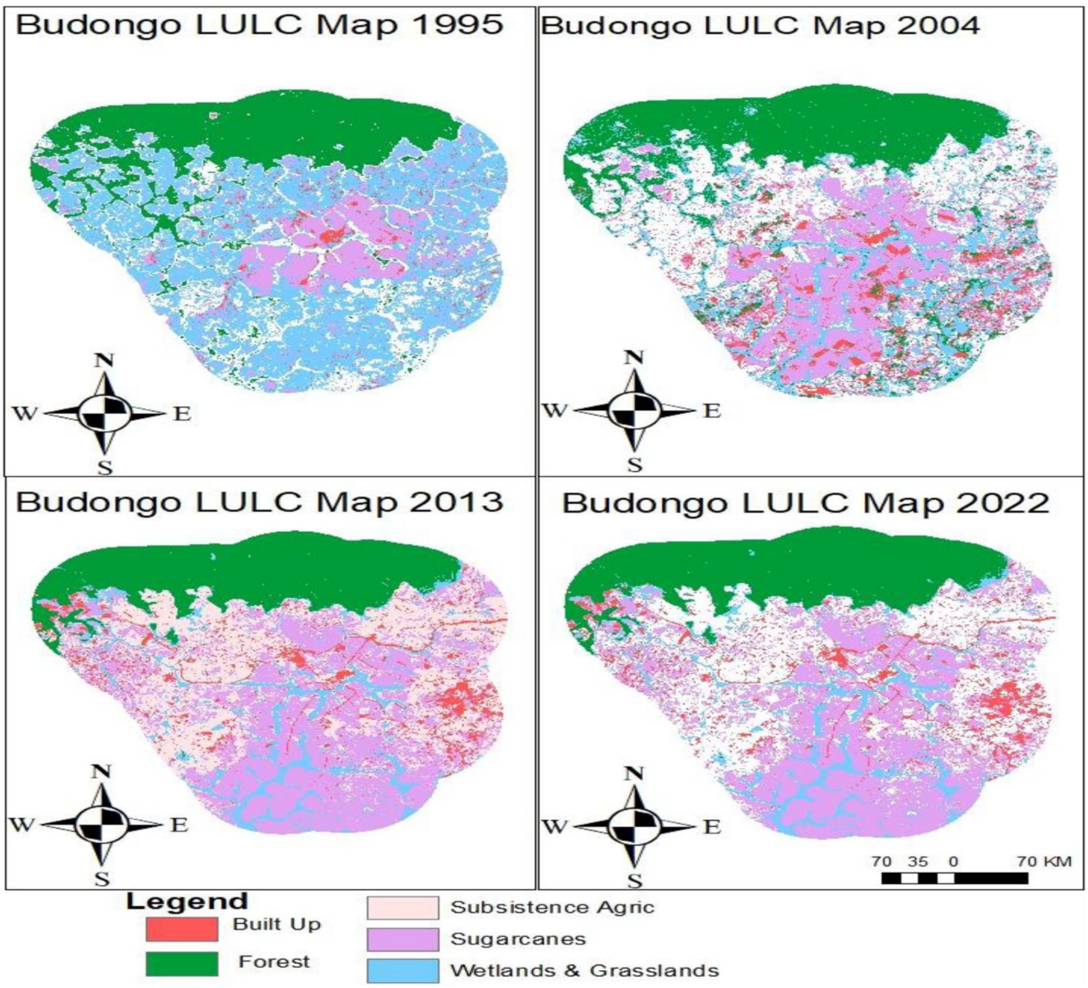

Figure 2. Spatio-temporal distribution of LULC around Budongo CFR (1995–2022).

Table 4. Land use and land cover change in 1995, 2004, 2013 and 2022.

	1995		2004		2013		2022	
LULC Classes	Area (sq.km)	LULC%	Area (sq.km)	LULC%	Area (sq.km)	LULC%	Area (sq.km)	LULC%
Built-up	11	2.4	24.7	5.3	25.2	5.4	32.4	7
Forest	110.9	23.9	123.3	26.6	111.6	24.1	103.3	22.3
Subsistence agriculture	82.8	17.9	128.2	27.7	124.2	26.8	132.7	28.6
Sugarcane	58.3	12.6	102.5	22.1	143.4	30.9	153.7	33.2
Wetlands & grasslands	200.6	43.3	84.9	18.3	59.2	12.8	41.5	9
Total	463.6	100	463.6	100	463.6	100	463.6	100

Table 5. Changes within land use land covers (1995–2022).

LULC Changes →	Percentage gain/ loss 1995 −2022			Cumulative percentage changes		
LULC Types ↓	1995–2004	2004–2013	2013–2022	1995–2004	1995–2013	1995–2022
Built-up areas	56.3	22.2	11.7	129.1	194.5	233.6
Forest	5.5	−5.1	−8	5.8	0.6	−6.9
Subsistence agriculture	35.4	−3.1	6.4	54.7	50.0	60.3
Sugarcane	43.1	28.7	6.7	75.8	146.0	163.6
Wetlands	−154.2	−33.3	−42.7	−60.7	−70.5	−79.3

Figure 2 and table 4 show that wetlands and grasslands were the dominant land cover types, accounting for 43.3% of the total land area in 1995 while 24% was forest cover. In the same year, commercial sugarcane covered 58.3 hectares (12.6%) of the total area, whereas the built-up area was 2.4%. Commercial sugarcane almost doubled in size (102.5 km^2) in 2004, it increased to 143.4 km^2 in 2013 and it was 153.7 km^2 in 2022 accounting for 33.2% of the total land area under study. Increase in the area under sugarcane growing was attributed to the intensification of commercial agriculture. The area of wetlands and grasslands declined from over 200 km^2 in 1995 to 84.9 km^2 in 2004, 59.2 km^2 in 2013, and 41.5 km^2 in 2022. Overall, the area of wetlands and grasslands dropped from 43.3% in 1995 %–9% in 2022 (table 4). Commercial sugarcane plantations have expanded into wetlands, grasslands, forests and grasslands.

A change in one land use land cover results in a corresponding change in another land use. In the study area, sugarcane plantations replaced wetlands, grasslands, forest cover and arable land, which included areas previously utilized for food crop cultivation. Table 5 presents the percentage change in area (km^2) per LULC class between 1995 and 2022. In 2004, the area of wetlands and grasslands dropped by −154.2% while subsistence agriculture and commercial sugarcane increased by 35.4% and 41.3% respectively between 1995 and 2004. By 2004, subsistence agriculture, forests, and commercial sugarcane plantations were the most dominant land use and land cover types around Budongo Forest. The built-up areas expanded from 11 km^2 in 1995 to 25.2 km^2 representing a 56.3% increase within this land use. By 2013, commercial sugarcane growing had become the dominant land use and land cover type, covering 143.4 km^2 and representing a 28.7% increase from 2004 (table 5). The area under subsistence agriculture dropped by 3.1% even when it was the second most dominant land use in 2013.

Forest area decreased by 5.1% from 117.3 km^2 in 2004–111.6 km^2 in 2013. Wetlands and grassland areas decreased by 33.3% from 2004 to 2013, while built-up areas increased by 22.2%. Commercial sugarcane was a major land use in the landscape. By 2022, the area of commercial sugarcane had increased by a further 6.7% followed by subsistence agriculture (6.4% gain). The forest cover dropped by 8%, wetlands and grassland areas dropped by 42.7% while built-up areas expanded by 11.7%. Cumulative changes within the different land uses revealed that the built-up area increased by 233.6% from 1995 to 2022 followed by a cumulative 163.6% increase in area under commercial sugarcane over the same period. Areas of subsistence agriculture increased by 60.3% while forest and wetland areas cumulatively dropped by 6.9% and 79.3% respectively. Thus, the biggest LULC changes occurred in the last decade (2013–2022).

3.3. Perceived effects of the land use land cover changes on livelihoods and ecosystem services

The study assessed local community perceptions of the effects of LULC changes on their livelihoods and ecosystem services. Results of respondents' perceived effects of LULC changes on livelihoods and ecosystem services are presented in table 6. These results are presented on a four-point Likert scale of zero (0) to three (3). A zero value represents no perceived effect of LULC change on the livelihood and ecosystem services parameters listed in the first column: 1 represents minor effect, 2 represents moderate effect, and 3 represents major effects. In this study, no LULC effect

Table 6. Perceived LULCC effects (percentage responses n = 156).

Livelihood aspects ↓	LULC Change effects			
Level of change →	0	1	2	3
Settlement patterns	6.4	4.5	1.3	87.8
Soil fertility	5.1	0	1.6	94.2
Social network and cohesion	12.2	2.6	10.9	74.4
Water availability	13.5	0.6	5.1	80.8
Food security	3.2	0.6	1.3	94.9
Land available for food production	3.2	1.3	3.8	91.7
Livestock production	10.3	2.6	20.5	66.7
Natural capital assets	3.8	3.2	16	76.9
Human-Wildlife Conflicts	9	3.2	18.6	69.2
Human-Human Conflicts	10.3	7.7	15.4	66.7
Access to land	3.8	0.6	1.3	94.2

means there was no noticeable change in the corresponding livelihood and ecosystem service parameter stated in the first column of table 6 that is attributed to LULC change, minor effects imply minimum consequence of LULC change on the livelihood and ecosystem services parameter while moderate effect indicates fairly noticeable difference in the livelihood aspect and major LULC change effects refers to overtly manifested effects of the change on the corresponding livelihood and ecosystem services attribute.

Over 96% of the respondents mentioned that changes in land use and land cover affected the livelihoods of the household and ecosystem services. Results revealed that settlement patterns were majorly affected (stated by 87.8% of the respondents). With regard to land resources, 94.2% stated that the change had a major effect. About 75% of the respondents stated that the change had a major effect on the local communities' social network and cohesion while 80% of the respondents mentioned that LULC changes affected water availability.

In relation to the local community's perceptions of LULC change effect on food security, 95% of the respondents stated that LULC changes had a major reduction in food security while 92% reported that the changes had major reduction in the land available for food production. However, LULC changes were perceived to have had no effect on livestock production. This finding was triangulated with local leaders' views during the key informant interviews. They confirmed that the main occupation of the local community members in the study area was crop cultivation for subsistence purposes and to a lesser extent livestock production making it hard to denote LULC effects on livestock production. The threats to livelihoods reported to have been escalated by LULC change were human-human conflicts (stated by 69% of the respondents) and human-wildlife conflicts (mentioned by 67% of the respondents) (table 6).

The study tested for differences in local community perceptions of the effect of LULC changes on livelihoods and ecosystem services using Mann-Whitney U tests, and OLS regression. Mann-Whitney U tests with a lowest mean rank of 70.2 indicate that LULC change impacts were associated with respondents' perceptions of shifts in settlement patterns ($p = 0.019$) and social network and cohesion ($p = 0.004$). OLS analysis with unstandardised beta coefficients (β) of perceived LULC change effects on ecosystem services and livelihoods was performed (see table 7). According to this analysis, each β represents the expected change in ecosystem service and livelihood parameter for a one-unit increase in the independent variable. Based on settlement patterns that are living in town (Kabango Town Council) and age, the model revealed statistically significant differences in the respondents' perceptions of the effects of LULC change on settlement with location showing $\beta = -0.326; p = 0.019$ and age $\beta = -0.014; p = 0.005$. Respondents perceived LULC changes were associated with shifts in their social network and cohesion in the town and in the countryside ($\beta = -0.539; P = 0.001$). Age was negatively associated with their perception of the effect of LULC changes on social network and cohesion ($\beta = -0.02; p = 0.000$).

In terms of perceived effects of LULC changes on water resource availability, results revealed that age, land size and sugarcane as a dominant type of land use were linked to respondents' perceptions of water resource availability ($\beta = -0.021, p = 0.000; \beta = -0.009, p = 0.019; \beta = -0.169, p = 0.044$). With regard to food security, respondents' location (residence in Kabango Town Council and Budongo Sub-County) ($\beta = -0.199; p = 0.034$) and age ($\beta = -0.008; p = 0.018$) had significant association with local community perceptions of LULC effects.

Age ($\beta = -0.013; p = 0.015$), land size ($\beta = -0.009; p = 0.009$) and commercial sugarcane growing ($\beta = -0.215; p = 0.007$) were significantly linked to the respondents' perception of LULC changes on livestock production. In terms of human-wildlife conflicts (HWC), gender ($\beta = 0.335;$

Table 7. Perceived LULC change effects on livelihoods and ecosystem services.

Factors	Estimate	Pr(>|t|)	Factors	Estimate	Pr(>|t|)
Settlement			Livestock		
Location	−0.326	0.019*	Location	−0.136	0.383
Gender	−0.022	0.874	Gender	0.216	0.172
Age	−0.014	0.005**	Age	−0.013	0.015*
Education Level	−0.044	0.602	Education Level	0.059	0.539
Size of Land	0.001	0.608	Size of Land	−0.009	0.009**
Sugarcanes	−0.033	0.63	Sugarcanes	−0.215	0.007**
Multiple R-squared: 0.079; P-value:0.051			*Multiple R-squared: 0.118; P-value: 0.004*		
Social Network and Cohesion			Natural Capital Assets		
Location	−0.539	0.001**	Location	0.005	0.962
Gender	0.103	0.533	Gender	0.064	0.608
Age	−0.02	0.000***	Age	−0.006	0.154
Education Level	−0.115	0.251	Education Level	0.038	0.617
Size of Land	−0.005	0.188	Size of Land	−0.000	0.976
Sugarcanes	−0.133	0.107	Sugarcanes	−0.118	0.057
Multiple R-squared: 0.146; P-value: 0.001			*Multiple R-squared: 0.037; P-value: 0.466*		
Water Resources Availability			Human-Wildlife Conflicts		
Location	−0.307	0.066	Location	−0.009	0.951
Gender	0.135	0.421	Gender	0.335	0.032*
Age	−0.021	0.000***	Age	−0.004	0.438
Education Level	−0.142	0.168	Education Level	0.003	0.975
Size of Land	−0.009	0.019*	Size of Land	0.001	0.703
Sugarcanes	−0.169	0.044*	Sugarcanes	−0.24	0.002**
Multiple R-squared: 0.147; P-value: 0.001			*Multiple R-squared: 0.087; P-value: 0.032*		
Food Security			Human-Human Conflicts		
Location	−0.199	0.034*	Location	−0.301	0.067
Gender	−0.000	0.996	Gender	0.253	0.126
Age	−0.008	0.018*	Age	−0.009	0.094.
Education Level	0.007	0.906	Education Level	−0.024	0.806
Size of Land	0.000	0.988	Size of Land	−0.009	0.009**
Sugarcanes	−0.063	0.179	Sugarcanes	−0.235	0.005**
Multiple R-squared: 0.075; P-value: 0.069			*Multiple R-squared: 0.126; P-value: 0.002*		
Soil Fertility			Access to Land		
Location	−0.073	0.473	Location	−0.191	0.062.
Gender	0.061	0.552	Gender	−0.002	0.984
Age	−0.005	0.152	Age	−0.006	0.085
Education Level	0.072	0.246	Education Level	0.021	0.743
Size of Land	−0.000	0.86	Size of Land	0.000	0.985
Sugarcanes	−0.063	0.211	Sugarcanes	−0.083	0.105
Multiple R-squared: 0.042; P-value: 0.374			*Multiple R-squared: 0.066; P-value: 0.122*		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

$p = 0.032$) and commercial sugarcane growing ($\beta = -0.240$; $p = 0.002$) was significantly associated with respondents' perception. These perceived effects are attributed to the knowledge that the ecological integrity of wildlife dispersal zones is often affected by land use land cover changes. The size of land ($\beta = -0.009$, $p = 0.009$) and commercial sugarcane growing ($\beta = -0.235$; $p = 0.005$) was linked to respondents' perception of the effect of LULC change on Human-Human Conflicts (HHC).

4. Discussion

4.1. LULC dynamics of Budongo CFR surrounding landscapes

Results of this study have affirmed that commercial sugarcane growing is the major land use land cover grown on different land sizes alongside food crops to support the livelihoods of the local communities around Budongo Forest Reserve. Settlement has consistently increased in land coverage over the years despite being the smallest land use type. This was attributed to rapid urbanization taking place and human population growth as a result of the arrival of migrant sugarcane workers in the area (Kusiima *et al* 2022). Growth in the migrant population seeking employment in commercial sugarcane plantations and sugar factories accounts for the increase in settlements and built-up areas (Mwavu *et al* 2018). Wetlands and grasslands were the dominant land cover types in 1995. However, the area under commercial sugarcane nearly doubled in 2004 and by 2013 and 2022, it was the most dominant type of land use. From these changes, it is clear that, while the area under commercial sugarcane was growing exponentially, the area under subsistence agriculture grew marginally. This cannot be disaggregated from the fact that commercial sugarcane farming is one of the oldest farming practices in Uganda, with a history dating back to the early 1920s (Mwanika *et al* 2021). Intensive large-scale agriculture, including sugarcane growth, was one of the leading LULC change drivers reported in literature (de Jong *et al* 2021). This study revealed that commercial sugarcane growing has reduced wetland and grassland areas. Commercial agriculture in Uganda has been reported among other wetland degradation and drainage drivers (Omagor and Barasa 2018) especially due to the motivation of quick monetary gains (Mwavu *et al* 2018). The built-up area shows a more or less sustained increase while the areas of forests, wetlands and grasslands continue to decline. Other studies have reported that the expansion of urban areas (de Jong *et al* 2021) and related human activities account for temporal and spatial changes in land use land cover (Agarwal *et al* 2020).

Generally, a change in one land use and land cover type results in a corresponding change in other land use land cover types (Majaliwa *et al* 2018, Mwavu *et al* 2018). In this study it was noted that sugarcane plantations have progressively expanded into wetlands and grasslands, forests and arable lands that were previously used for food crop production. This study also affirmed that sugarcane growing was currently the major land use type and a key driver of land use change. In addition, sugarcane was grown on almost all land sizes as a source of household incomes.

The areas under settlement consistently increased over the years despite being the smallest land use type. Studies undertaken in related contexts revealed that urbanization and human population growth account for consistent increases in built-up areas (Kalema *et al* 2015, Mohammed *et al* 2017). In this study, the influx of migrant populations seeking employment in the sugarcane plantations and sugar factory increased settlements and built-up areas. A study by Yadav *et al* (2019) revealed that increases in the human population coupled with the arrival of immigrants were responsible for forest degradation and deforestation as forest land was cleared to create room for settlement and farming. Settlements established as a result of population increase, commercial agriculture, urbanization and land tenure systems cause land use and land cover changes (Kullo *et al* 2021).

Expansion of agricultural land is one of the most cited drivers of land use, and land cover change in literature (Maina *et al* 2020). Local oral accounts revealed that commercial sugarcane growing was a dominant land use in the areas surrounding the Budongo Forest Reserve because of the growing interest in cash income obtained from the sale of sugarcane. This proposition also partly explains the continued wetland regression and loss of tree cover due to expansion of commercial sugarcane growing. Contrary to these findings, a study undertaken in the Nakasongola District close to the Budongo Forest Reserve revealed an increase in forest and tree cover partly due to stringent measures protecting forests as well as the establishment of plantation forests (Kuule *et al* (2022). It was clear from the results and the above discussions that, while the area under commercial sugarcane was growing progressively over time, the area under subsistence agriculture grew marginally. The built-up area increased steadily whereas the forests, wetlands and grassland areas declined. This study revealed that built-up areas cumulatively increased from 1995 to 2022 followed by the expansion of commercial sugarcane acreage. Li *et al* (2016) and Svarstad *et al* (2018) reported that most agricultural lands are reminiscent of how physical and socio-economic factors influence land use and land cover changes. It is clear from this study (figure 2 and table 4) that the largest LULC changes occurred from 2013–2022.

The results of the survey further revealed that LULC changes have affected the local communities' livelihoods and ecosystem services. This view was in tantum with the fact that LULC changes were known to affect the functioning of the earth's biological systems that support the livelihoods of the local people (Erdoğan *et al* 2013). LULC changes affect settlement patterns, soil fertility, social network and cohesion water availability, food security, land available for food production, escalating human-human conflicts and human-wildlife conflicts. Erdoğan *et al* (2013), Metternicht (2017) and Verheye *et al* (2014) reported the effects of land use land cover changes on livelihoods and attributed them to the competition between the different land-uses that hamper food production. In similar dispositions, Svarstad *et al* (2018) noted that LULC changes affects the livelihoods of local communities. In this study, there were differences in the perceived effects of LULC changes between the respondents in town settings and in the countryside. These can be attributed to the influx of migrant populations seeking employment in the sugarcane plantations and sugar factories that settle in the towns (Kusiima *et al* 2022), thereby changing social structures and networks. Perceptions were also influenced by gender, land use type, land size and age. In this case, the perceived effects could be due to abandonment of settlements in town as people migrate in search of jobs in rural areas with commercial agriculture (Hassan *et al* 2016, Kuule *et al* 2022).

The effects of land use and land cover change on water quality and quantity have been reported by Kalema *et al* (2015), Fu *et al* (2021), Majaliwa *et al* (2018) and Luwa *et al* (2020). Expansion of commercial sugarcane growing reduces land size that should be used for food production and ultimately affects the households' food security (Mwavu *et al* 2018). A similar view was held by Svarstad *et al* (2018) who noted that commercial agriculture increases famine and economic marginalization of the rural poor, who become dependent on the fluctuating commercial agricultural market. Similarly, the growth of human populations around protected areas, such as The Budongo Forest Reserve, accelerates land use change and contributes to human-wildlife conflicts which are exacerbated by migration and settlements (Estes *et al* 2012). There are circumstances under which land-use changes can lead to human-wildlife conflict as discussed by Zuo *et al* (2022) and these include the size of land owned by households and the land use type among others.

5. Conclusions and recommendations

LULC in the areas surrounding the Budongo Forest Reserve has changed from subsistence to commercial sugarcane growing triggered by the zeal to earn cash incomes. Secondly, areas of wetlands, grasslands and forests continue to decline due to expansion of commercial sugarcane growing. The expansion of commercial sugarcane plantations is attributed to an increase in the human population due to an influx of migrant workers to the Budongo forest areas in search of jobs in sugarcane plantations and the sugar factory. Thirdly, LULC changes are impairing the local communities' livelihoods and ecosystem services. There is a perceived decline in food security, accessibility to land for subsistence agricultural production, disruptions in local settlement patterns, social network and cohesion, natural capital assets, water resource availability and soil fertility, among others attributed to LULC changes. All these not only continue to threaten community livelihoods but also the natural capital assets and the associated ecosystem services within the Budongo forest surrounding communities. In light of this, it is imperative for stakeholders to participate in land use planning approaches. These may include establishing land zoning ordinances to protect wetlands and forest edges, enhancing alternative incomes and livelihood programmes such as apiary and agroforestry, among others. This will mitigate the adverse effects of LULC changes on ecosystem services and livelihoods of households. In addition, commercial sugarcane growing should be integrated into local level landscape land use planning to harmonize activities with other land uses and land covers. In this way, the negative effects of LULC will be mitigated in the landscapes that surround the Budongo Forest Reserve. All this notwithstanding, the general low levels of variation in perception of the effect of LULC changes on the assessed livelihood outcomes and ecosystem services as revealed in all OLS models suggest that there are other factors contributing to declining livelihoods of communities other than LULC changes. These factors ought to be examined, and direct attribution of the different LULC changes and the resultant livelihood outcomes examined if livelihoods' sustenance is to be fully achieved within the study area. Similarly, population dynamics corresponding to the LULC types and respective changes ought to be studied for proper attribution of the LULC change effects to the temporal shifts in the population of study area beyond the oral narrations.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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