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Research Article

Historical Perspectives of Land Use and Land Cover Change in the Sanga-Lake Mburo former Pastoral Rangeland Ecosystem, Uganda

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Abstract

Socioeconomic, political, and policy decisions by the government may influence the socioecological changes of the land use and land cover pattern for rangeland people over time. This paper examines the historical political, policy, and socioeconomic decisions that influenced land use and land cover changes in the former pastoral community in Sanga-Lake Mburo Rangeland Ecosystem in South Western Uganda. Data on historical events were documented from literature and supplemented by an opportunistic discussion with Sanga residents. Data on land use and cover change detection between 1987 and 2020 were provided by Landsat 5 TM and Landsat 8 OLI/TIRS images and from field observations. Images were processed using QGIS version 3.20.1 employing a semi-automatic classification plugin. Political decisions and government policies related to land tenure and reforms, socioeconomics, and demographic changes were noted as underlying drivers of land use and cover changes. The overall accuracies for classified maps of 1987 and 2020 were 80.36% and 89.81%, respectively. Notably, woodland cover in the protected area increased by 170.53% between 1987 and 2020, while built-up areas and farmland increased 1348.15% and 405.03%, respectively. In the same period, wetland cover in protected and unprotected decreased immensely by 46.06%. Bareland in the park decreased by 23%, while outside the park, it increased by 25.07%. This study concludes that land use and land cover change resulted from sociocultural changes, political and policy decisions on ranches, park management, and land tenure restructuring.

Keywords: Park, Political, Policy, Pastoralists, Vegetation, Sedentarization

Introduction

Globally, anthropogenic and natural factors are threatening rangeland ecosystems (Mugisha, 2002). Kimiti et al. (2016) report that since the 1950s, close to 10.7 million km^2 of the global land occupied by woodland and grassland has been converted to farmlands. The decline in the rangeland ecosystem in Uganda is experienced more in the cattle corridor, which stretches from the southwestern part of Uganda to the northeastern part of the country (NEMA, 2007). According to Olson and Berry (2003), the primary land use and land cover (LULC) issues in rangeland ecosystems are bush burning, deforestation, overgrazing, and inappropriate farming practices. The rapid vegetation conversion to farmlands could be attributed to intensifying and modernizing agriculture (Sambou et al., 2015). For example, shifting cultivation in agricultural expansion is the leading cause of deforestation in the Equater region in the Democratic Republic of Congo (Samndong et al., 2018). In the northern Atlantic forest in Brazil, 76% of the households rely on fuelwood (Godar et al., 2014).

LULC changes such as the conversion of grassland or woodland to farmland can increase the changes associated with natural forces (Smith et al., 2014). Satellite, ground-based, and tower observations indicate deforestation occurs during drier and warm conditions at local scales (Lawrence and Vandecar, 2015). Agricultural productivity is lowered by these conditions, as pasture and soil moisture contents are reduced, leading to conflicts for resources, migration, biodiversity loss, and among others (Alkama and Cescatti, 2016; Barni et al., 2015; Kweka et al., 2016; Lapola et al., 2014; İşcan and Yağcı, 2017). Land use influences the nutrient distribution and their supply by causing the alteration of the soil property and controlling the activity of microbes near the root zones. Cultivation causes the soil carbon to diminish within a few years of the conversion (Murty et al., 2002), reducing carbon sequestration (Robert et al., 2020) and can substantially lower the mineralizable soil nitrogen (Richter et al., 2000). The topsoil organic diminishes, thus reducing the productivity (Majaliwa et al., 2010). Therefore, severe land degradation can result in a nutrient loss (Tukarhirwa, 2004).

The primary land use in Sanga was livestock grazing because most of the people in the region were pastoralists. However, with time, the pastoralists adopted a settled lifestyle and started crop farming alongside livestock keeping. Due to the population pressure and sedentarization (Greg et al., 2019), the pressure on land has increased due to the need for grazing land, cultivation, and settlement, thereby

influencing the LULC changes (Mwanjolo et al., 2018). Furthermore, vegetation burning and livestock keeping in Sanga Subcounty cause the restructuring of landscapes and habitat modifications (Averbeck et al., 2012). The uncertain and erratic rainfall in rangelands can make rangeland ecosystems described as disequilibrium systems (Behnke and Scoones, 1992). The livestock production in such ecosystems is ideal when the livestock can be moved to locations with the best pasture at any time. However, sedentarization, land privatization, land subdivision, and population growth have made it hard for pastoralists to move their livestock from place to place (Mallarach, 2008). This problem is threatening their livelihood and affecting the land cover.

Currently, the conversion of natural ecosystems into other land use is a crucial challenge in Sanga. Since the park's creation in 1983 (Ayorekire et al., 2011; Hulme and Infield, 1998; Namara et al., 1994), there has been increased pressure on available natural resources such as woodland, soil, grassland, and wetlands. The creation of the national park in 1983 also reduced land for pastoralism (Ayorekire et al., 2011; Emerton, 1999b), causing more land crises due to reduced grazing land. Woody vegetations are highly exploited for shifting cultivation, wood, fuelwood, and charcoal (Basamba et al., 2016) as population increases and demand for construction and fuelwood increases (Elias et al., 2019). Within the cultivated land in Sanga, crop cultivation is intensifying, leading to land subdivisions. Furthermore, this rangeland experiences competition for forage and pasture by livestock and wildlife (Nyamasyo and Kihima, 2014) from the park. Moreover, the traditions and taboos that excluded farming communities from cultivating the landscape near Lake Mburo have changed, leading to the constant loss of the exclusive pastoralist landscapes (Mallarach, 2008). As a result of these changes, soil erosion is observed, wetlands and grazing lands are shrinking, and frequent droughts are experienced. We noted several studies in Uganda on LULC (Mbaziira, 2014, 2019; Mwanjolo et al., 2018; Nakalembe et al., 2017;

Solberg et al., 2018). However, none of the studies adequately addressed historical drivers of LULC change in ecosystems surrounding a park focusing on former pastoralists with a unique history.

Our study focused on assessing the historical drivers of LULC changes, mapping LULC, and quantifying LULC changes between 1987 and 2020. The purpose of our study was to highlight how political and policy decisions in the past, sociocultural and demographic changes affected the current LULC. The understanding of the causes of LULC changes and how LULC changed can be used for predicting future trends. This understanding is essential for sustainable land use by the people who depend on the fragile rangeland ecosystems, particularly in Sanga. We asked what the political and policy decisions, cultural and socioeconomic changes that influenced LULC changes are and how they influenced them. We also asked how LULC cover status was in 1987 and 2020, the cause of such status, the class of LULC that changed most, and the main drivers for the change.

Materials and Methods
Area of study
The study was conducted in Sanga rangeland located in Kiruhura District, South Western Uganda, located at 0°22'22.50"S to 0°42'39.59"S and 30°47'06.04"E to 31°0201.25"E (Fig 1) and with an elevation of about 1800 m above sea level. Temperature ranges from 17ºC to 30º, and the region receives a double maximum rainfall pattern of 900 mm on average per year, which falls from March to May and August to October (Tibezinda et al., 2016). It is gently sloppy and with runoff during heavy rainfall. The area experiences unpredictable, scarce, and unreliable rainfall, which often leads to crop failure. The site has varying types of soils. In lowlands, the soil is black-grey, hard clay loams, reddish-brown with sandy structure. The vegetation comprises savannah (Basamba et al., 2016)). The main economic activity is pastoralism practiced by 70 percent of the population.
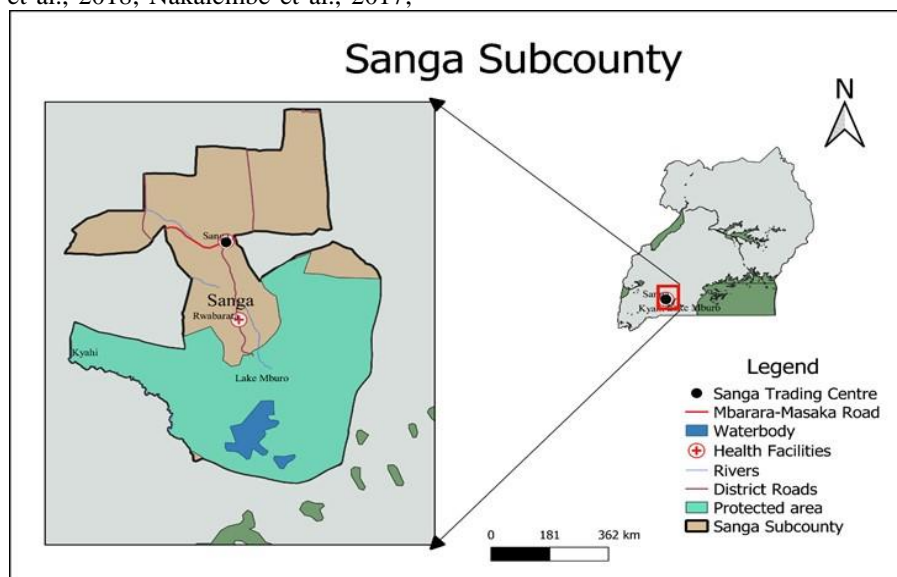

Fig. 1: Inset is a map of Uganda showing the location of the Sanga sub-county

Data collection
Data on historical drivers of LULC change before and during the period under review -1987 to 2020 were obtained from published journals, working papers, thesis, government, and non-governmental reports on events. The literature materials were obtained from Google scholar and government and non-government websites by searching for land use in Sanga and Lake Mburo. We followed an approach called Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Luwa et al., 2020), which involved searching, screening, and considering the relevant materials. We searched 205 articles, discarded 100 articles for duplication, and screened the remaining 105. We considered thirty literature materials written in English. The literature materials included; three books, seven published journals, four research papers, seven working and discussion papers, three thesis, and six government and non-government reports. These data from literature were supplemented by opportunistic interactions with our field assistant, two local leaders, and seven other older people from Sanga. We preferred the PRISMA approach because it allows researchers to identify trends and common themes on quantitative and qualitative methods without the predefined bias of inclusion and exclusion (Luwa et al., 2020).

Table 1: The Landsat images used in the classification of LULC in the Sanga sub-county

Landsat	Year	Path/Row	Band combination
Landsat 5 TM	1987	172/60	7-5-4-3-2-1
Landsat 8 OLI/TIRS	2020	172/60	7-6-5-4-3-2

Table 2: Sanga Subcounty LULC description as used in classification

Land use and land cover type	Description
Eroded/Bare land	The area with very little or no vegetation cover
Grassland	Natural grass or grass-like vegetation
Waterbody	Open water bodies, lakes, and water dams
Wetland	Permanently/seasonally waterlogged areas with vegetation cover
Woodland	Area with woody vegetation species both natural and exotic
Built-up	Artificial structures, mainly the buildings
Farmland	Cultivated areas with perennial and annual crops

Data on LULC changes were obtained from satellite images of Landsat from USGS Earth Explorer (https://earthexplorer.usgs.gov). Thematic Mapper (5 TM) images captured on February 1987 and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared

Sensors (TIRS) images captured on January 2020 provided data on LULC changes between 1987 and 2020, as summarized in Table 1. LULC classes identified were farmland, grassland, woodland, bare land, wetlands, water body, and built-up areas. The description of these LULC is provided in Table 2 below. Ground truthing data through field observation were used to validate the 2020 map using 50 ground control points for each land cover class collected using a GPS. The interaction with our field assistant and nine other Sanga residents provided supplementary information about LULC change.

Image processing and analysis
1987 Landsat 5 TM and 2020 Landsat 8 OLI/TIRS images were imported into QGIS version 3.20.1 and bands loaded to semi-automatic classification plugin version 7.9.5(Congedo, 2021). Then the images were clipped to the area of interest, and then we enhanced the images by conducting DOS (Dark Object Subtraction) atmospheric correction. Supervised classification methods were used in the classification of the images and to produce maps for LULC by creating ROIs (Regions of Interest) after creating training inputs. The maximum likelihood function was used to generate land cover maps. Land cover classifiers most prefer this function because it produces precise results, and cluster statistics have a normal distribution (Sintayehu and Kassaw, 2019). LULC change detection was generated to show the conversions using the same tool and plugin. Accuracy assessments of maps were assessed using the Kappa statistic and error matrix (Mbaziira, 2019) to validate 1987 and 2020 classified maps. For 2020, ground truth data by field observations and from Google satellite images were used. Ground control points (GCP) were collected from the field using a GPS and others obtained from google satellite images, especially for land cover in the protected area. Besides field observation and the input of our assistants, Google satellites images provided further interpretations and accuracy assessment of the classified map for 2020. We collected 50 GCPs for each. 1987 mages interpretation was used in the accuracy assessment of the 1987 classified map, and GCPs were obtained through stratified sampling to determine the sample size using this formula (Olofsson et al., 2014);

$$N= (\sum i = 1(Wi*Si)/So)^2 \ldots\ldots\ldots\ldots (Eq. 1)$$

Where:
Wi=proportion of the mapped area of class i;
Si=Stratum i's conjectured standard deviation;
So=the overall accuracy' expected standard deviation;
N= total sample size.

A sample size of 882 of the total area of the Sanga sub-county was produced by conjecturing standard deviation of the strata and user's accuracy as recommended by Olofsson et al. (2014). A rough approximation for the sample size for each land

use/cover class was determined by considering the mean value between weighted distribution (Ni=N*Wi) and equal distribution (Ni=N/c).

(Ni= N*Wi+ N/c)/2……... (Eq. 2).

Where:
C=total number of classes (7);
Ni=sample size of class i.
Thus, built-up had a sample size of 63, farmland had 70, bare land had 98, wetland had 126, waterbody had 73, grassland had 267, and woodland had 185 GCPs, respectively. The following equations were used in calculating land use/ cover change, percentage land use/cover change, and percentage rate of land/cover change;
LULC change =CL-PL; percentage LULC change= (CL-PL/PL)x 100 and percentage rate of LULC change = percentage change/number of years.
Where; CL is the current LULC in 2020 and PL is the previous LULC in 1987.

Results
Historical drivers of LULC change before and between the years 1987 and 2020

Table 3 below lists the historical drivers of LULC change in Sanga, both in protected and unprotected areas, prior study, and during the study.
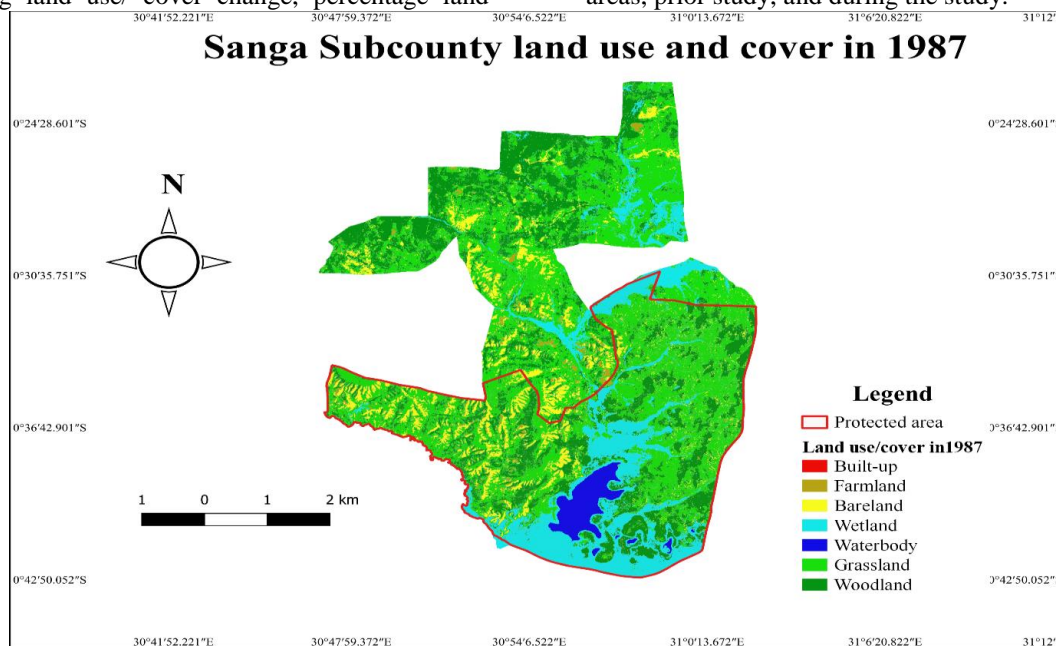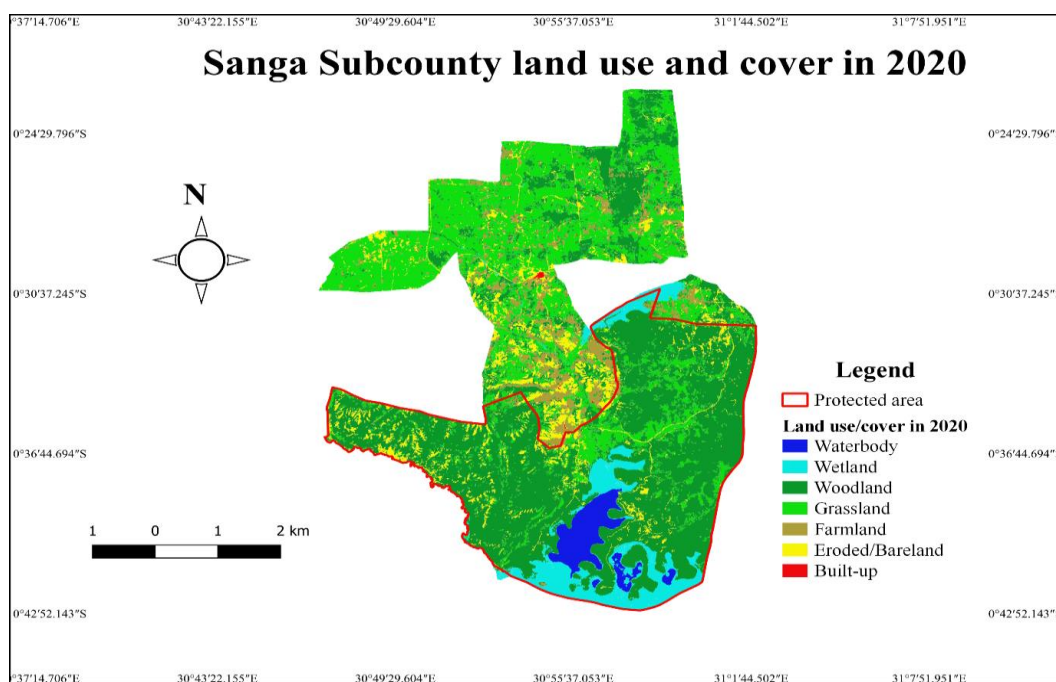

Fig. 2: LULC of Sanga Subcounty in 1987.

Fig. 3: LULC of Sanga Subcounty in 2020

Table 3: Historical drivers of LULC before and during the study

Date	Historical drivers of LULC change	Result	Source
Pre-1970	• Establishment of government-sponsored ranches in the "cattle corridor" of Uganda • Leasing communal land to individual ranchers	• Sedentarisation of pastoral Bahima elite who acquired ranches • Traditional pastoralists that did not acquire ranches displaced into other parts of Uganda • Land conflicts over grazing areas intensified • encroachment of cattle traditional pastoralists into the reserve	Byakagaba et al., 2018; Tukahirwa, 2002; Kafureka, 1992; Ayorekire, 1999; Ayorekire et al., 2011; Ochieng, 2011; Ochieng, 2019;
1973-1977	• Additional privatization of ranches to private people • Land allocation to absentee property owners within ranches in communal land	• Corruptly allowing pastoralism into the Lake Mburo Game Reserve • Land evictions and land grabbing • Increased reclamation of the wetlands and reduced woodlots • Land use conflict escalated in the reserve	Tukahirwa, 2002; Emerton, 1999; Bernard et al.,2010; Kamugisha & Ståhl, 1993
1971-1986	• Political turbulence, war, and internal conflicts (a series of government changes)	• Conservation activities in and around Lake Mburo Game Reserve were paralyzed • Forceful displacement and eviction of people and their livestock into Lake Mburo Game Reserve • Depopulation of wildlife through extensive poaching and encroachment • Land in communities abandoned • Death and reduction of livestock • Habitat reduction reducing biodiversity • Adoption of crop farming by traditional cattle keeping and • An influx of internally displaced people, including migrant agriculturalists	Hulme & Infield, 1998; Smith, 2012; Marquardt, 1994; Kafureka, 1992; Emerton, 1999; Ochieng, 2011; Ochieng, 2019; Kamugisha & Ståhl, 1993
1983	• Status of Lake Mburo Game Reserve uplifted to Lake Mburo National Park (LMNP) (allegedly done as a punishment of local people that did not support the national government at a time) • Park boundaries delineated	• Animal wildlife conflicts enhanced • The conservation effort of the park improved • Escalated human-wildlife conflicts and between herders and elite ranchers • Overgrazing of marginal land close to the park	Ayorekire, 1999; Kafureka, 1992; Hulme & Infield, 1998; Emerton, 1999; Namara et al., 1994; Wurzinger et al., 2009; Marquardt et al., 1997; Barrow et al., 1993; Kamugisha & Ståhl, 1993
1986	• Degazettement of part LMNP – through reallocation of land to local communities	• Park reduced by 60% • An influx of people from other areas in search of free land promises • Retaliation of local people against wildlife authorities • Wildlife and park infrastructure destroyed	Emerton, 1999 Hulme & Infield, 1998; Namara et al., 1994; Barrow et al., 1993; Ntiamoa-Baidu et al., 2001; Kamugisha & Ståhl, 1993

Period			References
1987-1995	• Resettlement of migrants from Luwero under the Kanyaryeru settlement scheme • Conservation effort intensified by the park management (conservation by protectionism approach) • Settlement of landless people by Ranch Restructuring Board (RRB) • Land tenure restructuring	• Resentment and hostilities against migrants by residents • Indiscriminate clearing of natural woodland into farms • Increased pressure in grazing land • New entry of squatters in ranches with the hope of acquiring free land • Squatter invaded ranches after displacement from the park • Increased land tenure security changing from the pastoralism lifestyle and adopting mixed farming • Increased Park natural regeneration • Land subdivisions and fragmentations • Intensified farming	Namara, 1996; Kafureka, 1992; Hulme & Infield, 1998; Byaruhanga & Kigoolo, 2005; UWA, 2015; Ochieng, 2011; Ntiamoa-Baidu et al., 2001;
1991-1996	• Government policies on banning cultivation in the park • Establishment of the Community Conservation for Uganda Wildlife Authority project, which United States Agency International Development (USAID) and Swedish International Development Agency (SIDA) funded for and implemented by the Uganda National Parks and African Wildlife Foundation • Revenue sharing policy • Uganda Wildlife Authority (UWA) establishment • LMNP Management Plan	• Woodland and grazing land diminishing outside the park • Wetland encroachment outside the park • Increased conservation in the park • Modern farming and adoption of exotic breeds •	Emerton, 1999; Tukahirwa, 2002; Tukarhirwa, 2004; Olsen et al. 2004; Rannestad et al. 2006; Ochieng et al., 2020 Ochieng, 2011
2004	• Habitat approach focusing on invasive plant species	• Selective removal of *Acacia* led to faster and thicker growth of other woody species	UWA, 2015
2010-2015	• Agricultural intensification and diversification • Community projects	• Grassland converted to farmlands • Schools, health centers, and church construction	FAO, 2017 Ochieng, 2019 Ochieng et al., 2020
2015-2020	• The general management plan is ongoing	• Natural habitat restoration through natural regeneration within the park • Increased pressure on land attributed to human population	UWA, 2015 NEMA, 2016 USAID, 2017 USAID, 2015

Land use and cover change in 1987 and 2020

LULC in 1987 and 2020 are shown in Figures 2 and 3, respectively. The overall accuracies for classified maps of 1987 and 2020 were 80.36% and 89.81%, respectively. Additionally, the kappa hat classifications for 1987 and 2020 were classified were 0.71 and 0.85, respectively. The protected area boundaries are also shown.

Figures 4 (a) and (b) show that waterbody, bare land, and built-up had almost the same proportional land coverage in 1987 and 2020. However, the proportion of wetland and grassland cover was higher in 1987 than in 2020. On the other hand, the proportion of woodland and farmland cover in 1987 was lower than in 2020. Furthermore, Table 4 above shows that eroded/bare land did not significantly increase. However, there was a very significant increase in built areas and farmlands. There was an increase in woodland and waterbody cover in the same period. On the other hand, grassland and wetland cover decreased, with wetland decreasing by more than half of its coverage in 1987.
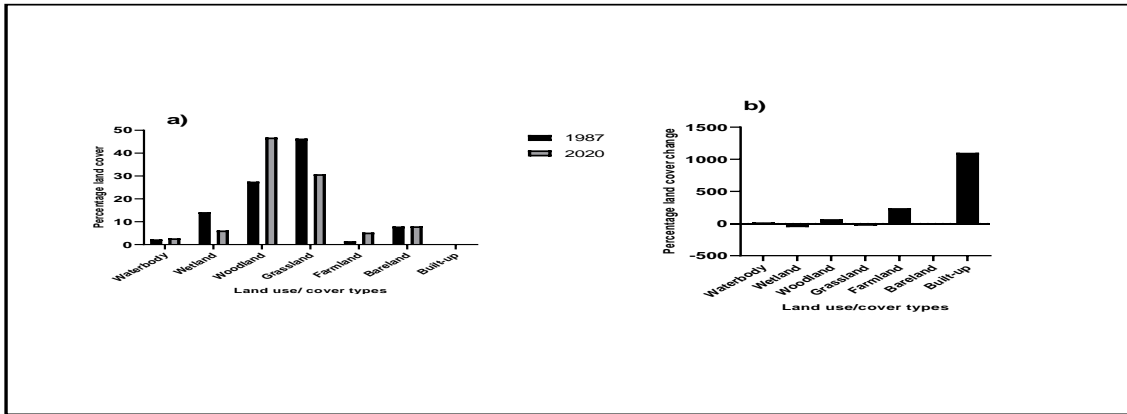
Fig. 4 (a) and (b): The percentage land cover and percentage land cover change between 1987 and 2020 in the Sanga sub-county.

1987-2020 LULC change in the protected area of Sanga Subcounty

The total area of the protected area or the park was about 30,027 hectares. Within the protected area's boundaries (Lake Mburo National Park) of Sanga, the significant change in LULC occurred in wetland, woodland, built-up, and grassland cover, as Figures 5 (a) and (b) show. Wetland cover in 1987 was 19.184% of the protected area, and in 2020, it was 10.353%, which was a 46.061% decline at a rate of 1.396% per year. On the other hand, the percentage occupied by woodland in 1987 was 24.484%, and in 2020 it was 66.353%. Grassland, on the other hand, covered a percentage area of 43.346% in 1987 and 11.802% in 2020. Its cover decreased by 72.787%, which was a 2.206% decline per year. Bare land cover declined by 23.008%, dropping at the area of 0.697% per year. The built-up area occupied the most negligible percentage in 1987 and 2020 at 0.002% and 0.005%, respectively. However, built-up had the highest gain with 157.143% and changed at 4.762% per year.

Fig. 5 (a) and (b): The percentage land cover and percentage land cover change between 1987 and 2020 in the protected area.

1987-2020 LULC conversion in the protected area of Sanga Subcounty

The conversion of LULC between 1987 and 2020 in the protected area occurred mainly in woodland and wetland (Table 4). Wetland lost about 5,756.31 hectares against the gain of 3107.07 hectares. It almost lost to all other land use/cover types except built-up area but lost mainly to woodland (2,218.95 hectares), grassland (459.72 hectares), and waterbody (193.68 hectares). Woodland cover, on the other hand, gained 19,912.41 hectares and lost 7,350.03 hectares. The gain was from all land-use types, but it was acquired mainly from wetland (2218.95 hectares), grassland (10,042.74 hectares), and bare land (1,203.84 hectares)

Table 4: Conversion matrix between 1987-2020 in the protected area of Sanga sub-county

Land use/cover change from 1987	Land use/cover to in 2020							
Land use/cover type	Waterbody	Wetland	Woodland	Grassland	Farmland	Bareland	Built-up	Total
Built-up	0	0	0.45	0	0	0.18	0	0.63
Farmland	1.98	0.99	188.01	40.41	2.61	73.17	0.36	307.53
Bareland	0	1.08	1203.84	403.65	15.66	668.34	0	2292.57
Wetland	193.68	2769.39	2218.95	459.72	17.73	96.84	0	5756.31
Waterbody	1277.19	19.08	0.27	0	0	0	0	1296.54
Grassland	0.36	83.88	10042.74	2083.77	68.94	725.40	1.26	13006.35
Woodland	78.75	232.65	6258.15	554.31	23.49	202.68	0	7350.03
Total	1551.96	3107.07	19912.41	3541.86	128.43	1766.61	1.62	30009.96

1987-2020 LULC change in unprotected area in Sanga sub-county

The unprotected area of the Sanga sub-county covered about 25,274 hectares. The changes in LULC occurred mainly in built-up areas, farmlands, woodland, and wetland cover, as shown in Figures 6 (a) and (b). Wetland in 1987 covered 8.05%, but in 2020 its coverage was 0.94%. The percentage decline was 88.34%, at a rate of 2.68% per year. Woodland occupied 31.30% of the unprotected area in 1987 and 24.18% in 2020. Thus, the percentage area covered by woodland declined by 22.81%, which decreased by 0.69% per year. Farmland covered 2.17% and 10.96% in 1987 and 2020, respectively, increasing by 405.03% at 12.27% percent. Built area in 1987 covered 0.01% and 0.14% in 2020 respectively but had an enormous gain of 1348.15% at 40.85% per year.
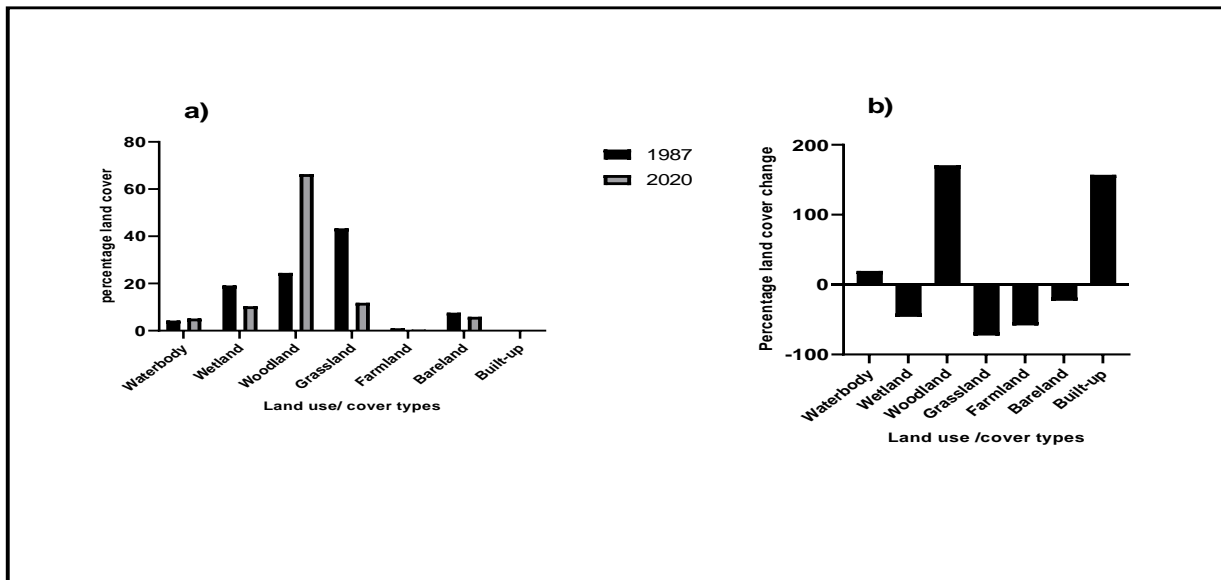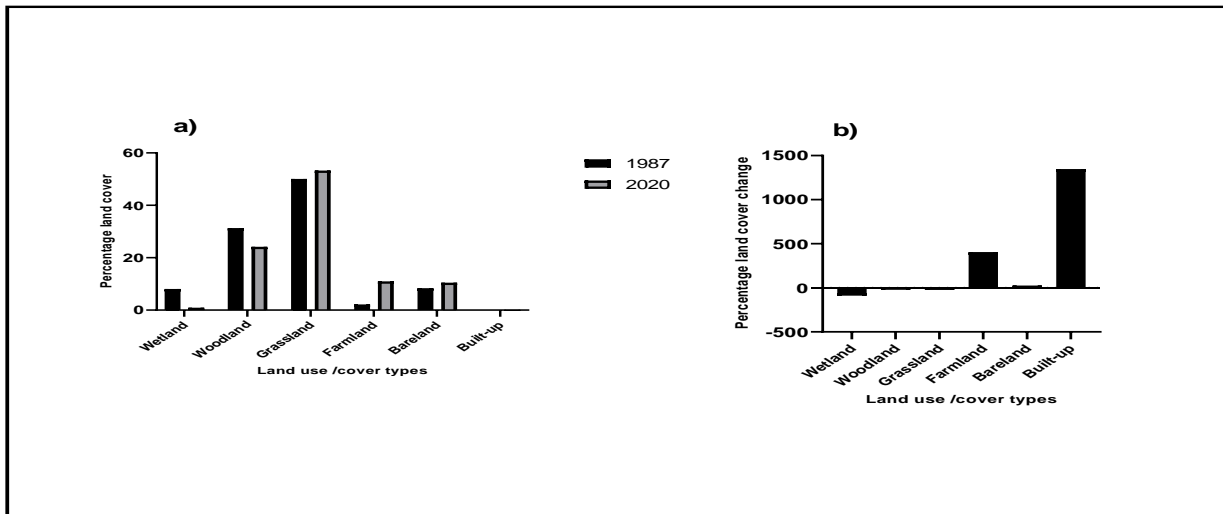

Fig. 6 (a) and (b): The percentage land cover and percentage land cover change between 1987 and 2020 in the unprotected area

1987-2020 LULC conversion in the unprotected area of Sanga Subcounty

Between 1987 and 2020, farmland acquired a total area of 2,766.69 hectares of land and lost 547.74 hectares in the unprotected area of Sanga (Table 5). In that period, 1639.08 hectares of grassland, 181.26 hectares of wetland, 117.90 of bare land, and 802.35 of woodland cover got converted into farmland. Moreover, woodland lost more cover than it gained. It lost 7,905.24 hectares against a net gain of 6,106.23. More of the woodland cover was converted into 4,854.33 hectares of grassland, 802.35 hectares of farmland, and 355.05 hectares of bare land. Built gained more land cover of 35.19 hectares and lost only 2.43 hectares.

The gain was mainly from 12.33 hectares of bare land, 21.15 hectares of grassland, and 1.26 hectares of woodland. Bareland cover also increased to 2,647.80 hectares against the net decrease of 2115.54 hectares. The leading cause of increased bare land cover was the loss of 223.92 hectares of farmland, 56.62 hectares of wetland, 1,251.18 of grassland, and 355.05 hectares of woodland. Wetland lost 2,032.83 hectares and gained very little coverage of 237.33 hectares. The significant loss was 666.99 hectares of woodland, 924.03 hectares of grassland, 181.26 hectares of farmland, 56.52 hectares of bare land, and a small portion of 0.27 hectares of built-up.

Table 5: Conversion matrix between 1987-2020 in the unprotected area of Sanga sub-county

Land/cover change from 1987	Land use/cover change to in 2020 (Ha)						
Land use/cover types	Wetland	Woodland	Grassland	Farmland	Bareland	Built-up	Total
Built-up	0.36	0.09	1.71	0	0.27	0	2.43
Farmland	0.09	105.03	192.42	26.10	223.92	0.18	547.74
Bare land	0.54	278.01	945.90	117.90	760.86	12.33	2115.54
Wetland	203.76	666.99	924.03	181.26	56.52	0.27	2032.83
Grassland	27.54	3168.90	6540.57	1639.08	1251.18	21.15	12648.42
Woodland	5.04	1887.21	4854.33	802.35	355.05	1.26	7905.24
Total	237.33	6106.23	13458.96	2766.69	2647.80	35.19	25252.20

Discussion

Political and policy decisions and socioeconomic changes in the past were identified as the leading underlying causes of LULC changes (Olson et al., 2004) in Sanga. These drivers influenced LULC to change differently in protected and unprotected areas of the Sanga-Lake Mburo ecosystem due to different land practices in both areas. Government policy changes were prominent causes of the LULC changes. These policies included; park creation, land restructuring, settling of landless people, promoting modern agriculture, and sedentarization of livestock keepers. Sociocultural, economic, demographic factors and political decisions had some influence on ecological changes.

Political and policy decisions may influence the LULC change through the displacement of people, corruption, and reluctance by the government officials to protect natural resources in protected areas from exploitation. Political crisis also paralyzes the conservation activities in the protected area leading to change in LULC. For example, the establishment of ranches, privatization of communal land, and subsequent displacement of landless pastoralists into the then Lake Mburo Game Reserve caused LULC to change in the protected area (Byakagaba et al., 2018; Emerton, 1999; Hulme & Infield, 1998; Kamugisha and Ståhl, 1993; Tukahirwa, 2002). Migrants established farmlands in the park (Emerton, 1999; Kafureka, 1992; Kamugisha and Ståhl, 1993; Marquardt, 1994; Smith, 2012) without deterrent from the conservationists. Additionally, people who were evicted from communal land and acquired land corruptly in Lake Mburo Game Reserve also caused the loss of vegetation, reclamation of the wetland, and increased grazing pressure (Kamugisha and Ståhl, 1993; Ochieng, 2011; Ochieng, 2019, Tukahirwa, 2002). Therefore, these factors explain why bareland cover was high and woodland cover was low in the protected area in 1987 compared to 2020. Furthermore, delineating the land exclusively for conservation by the government may reduce land availability to other users leading to competition for natural resources available, causing overexploitation of

natural resources. The consequences of the natural resources' exploitation are land conflict and overgrazing, leading to some eroded and bare land as observed outside the park. Creation of the park and degazetting part of it (Ayorekire, 1999; Barrow et al., 1993; Emerton, 1999b; Hulme and Infield, 1998; Kafureka, 1992; Kamugisha and Ståhl, 1993; Marquardt et al., 1997; Namara et al., 1994; Wurzinger et al., 2009) is therefore one the causes of change in LULC (Barrow et al., 1993; Emerton, 1999; Wurzinger et al., 2009). Land conflicts that began in 1983 are still going on (Government of Uganda, 2015), which a local leader with who we interacted confirmed. These disputes lead to poor land management and land fragmentations.

Furthermore, Douglas and Rebecca (2017) agree that the presence of the park is a challenge to the community. The ongoing habitat management implementation in the park have left scarce land for the farmers and pastoralists, thereby causing more pressure on woodland, wetland, and grassland, contributing to eroded/bare land cover and increase of farmlands and settlement (NEMA, 2016; USAID, 2015; USAID 2017). Our field assistant and two other elderlies also agreed that the park had reduced availability of land for grazing and farming, especially near the park where farms and eroded areas are highly experienced due to increased demand for land resources.

The increased conservation effort may restore vegetation cover, as observed by the increase in woodland cover in the park between 1987 and 2020 due to the government's commitment to improving conservation. The establishment of community conservation projects and revenue-sharing policies (Emerton, 1999; Hulme and Infield, 1998; Marquardt et al., 1997; Tukahirwa, 2002) and exclusion of people from the park curbed tree clearing and burning of vegetation (Rannestad et al., 2006). The outcome of these actions and decisions was increased woodland regeneration (Olsen, 2016) and reduced grassland and bare land cover in the park. However, this exclusivity can have an adverse environmental impact in terms of woody encroachment. A haphazard removal of woody

species can exacerbate the situation. For instance, the attempt by park management to restore habitat to its natural state by reducing woody species backfired as other woody species regenerated very fast (UWA, 2015). The open savanna in 1987 is now covered with woody species (NEMA, 2016; USAID, 2017) of mainly native *Acacia* species (Williams, 2018), which have reduced habitat in some parts of the park (UWA, 2015).

The immigrations and population increase demand for land for food production and settlement, thereby increasing pressure on woodland. Studies by WoldeYohannes et al. (2018) in Ethiopia report that migrations increase settlements and crop cultivation. In the study area, the refugees who settled near the park from Luwero indiscriminately cleared trees to create land for farming to support themselves after losing their livestock through wars (Mugisha, 2002; Namara, 1996; Olson et al., 2004). In addition to immigration and population increase, land tenure security and land restructuring policy can be attributed to tremendous growth in farmlands and built-up areas (Byaruhanga and Kigoolo, 2005; Hulme and Infield, 1998; UWA, 2015) since the pastoralists adopt settled life. The government's promotion for commercialized and modernized agriculture, further privatization of the land, and sedentarization (Tukahirwa, 2002; Mugisha, 2002; Olson et al., 2004; Byenkya, 2004; Wurzinger et al., 2009) also causes increased settlements and farmlands. Intensified modernized agriculture, for example, rearing of exotic breeds, also requires clearing vegetation to provide grazing land for exotic breeds (Ochieng et al., 2020), causing a reduction in woodland cover outside the park. Katushabe (2014) noted that farmers who adopted exotic species cleared woodland. We also observed that pastoralists are still clearing woodland in their ranches. Built-up areas and farmland increase were further boosted by the government expenditure of proceedings from the sport hunting in supporting arable farming, roads, and semi-permanent house construction (Ochieng, 2019; Ochieng et al., 2020). Other factors, such as restricting communal grazing land due to fencing of land by private owners (Kisamba-Mugerwa, 1995) necessitated settlements. Settlements are still growing in Sanga as the population grows, whereby Sanga town and other small villages are developing quickly along the paved and unpaved tracks towards the park's gate (USAID, 2017).

The decrease in woodland cover outside the park was also reported by NEMA (2021), who observed that land cover reduced due to charcoal burning and the need for fuelwood as the population grows (NEMA, 2016; USAID, 2015; USAID, 2017). People in rangeland areas depend on wood for cooking (Mbaziira, 2014) and constructing enclosures for their livestock that keep away predators at night (Olson et al., 2004). Additionally, burning grassland in the Sanga region was a common practice to improve the palatability of the pasture, thereby changing the

vegetation climax (Ayorekire, 1999) and reducing vegetation cover. Furthermore, extensive cutting of woodland for charcoal production (Nagasha et al., 2019; NEMA, 2016; USAID, 2015; USAID, 2017) causes the reduction of the woodland vegetation cover (Mugatha, 2002; Mugisha, 2002; Olson et al., 2004).

The culture change (Greg et al., 2019), taboos, and economic development (Mallarach, 2008), for example, changing pastoralists' diet habits from mainly animal-based to a plant-based diet and need to diversity income, can cause change LULC by increasing farmlands. Currently, the pastoralists are practicing mixed farming (Pearson et al., 2015) which is the reason for the increase in farmlands. FAO (2017) reported that some grasslands were further transformed into farmlands as more pastoralists adopted farming.

Soil erosion in hillslopes, along cattle tracks, and around watering points (Marquardt et al., 1997; Namara et al., 1994) and overgrazing may cause the current eroded / bare land cover. Moreover, the movement of livestock and pastoralists during the drought season for the search of pasture destroy soil, grass vegetation, and trees are cut to pave the way for settlement and establishment of livestock enclosures (Greg et al., 2019; Basamba et al., 2016), the practice that sometimes leaves the land bare. For instance, the current bare land cover in the park is caused by the pastoralists who are allowed to access water in the park during the drought season (UWA, 2015; Nagasha et al., 2019). It was also noted by Basamba et al.(2016), Pearson et al.,(2015 and Nabasumba et al.(2016) that commercial ranchers keep a considerable large number of cattle as much as their land can allow leading to grassland and soil destruction (Tukarhirwa, 2004), thereby increasing bare lands

Wetland cover declined in protected and unprotected areas, also a trend observed countrywide (NEMA, 2016). NEMA (2021) also reported a similar finding that between 2005 and 2015, wetlands have declined in the agro-ecological zone where we carried out our study. Wetlands were reduced immensely due to encroachment and ecological changes such as severe droughts (Nagasha et al., 2019; Mugisha et al., 2019; Government of Uganda, 2015; Oxfam, 2008). USAID (2010) observed an increase in temperature by 0.8°C during the rainy seasons, which can cause climate variability. Besides prolonged droughts, wetland degradation has been attributed to intensified farming activities, poor farming practices, overgrazing, and increased population growth (NEMA, 2016; Olson et al., 2004; USAID, 2017). The impacts of termites, wetland degradation, overstocking, charcoal burning, and deforestation are attributed to increased global warming leading to frequent droughts (Government of Uganda, 2015) that may have affected the reduction of wetland cover.

Conclusion

Policy and political decisions mainly influenced LULC change trends observed between 1987 and 2020 in

protected and unprotected areas. The population increase, sociocultural and socioeconomic changes were also the influence of land use and land cover change outside the park. Accordingly, built-up areas, farmlands, woodlands, grasslands, and wetlands cover changed significantly. The change occurred slightly differently in protected and unprotected areas. In protected areas, bare land and grassland cover decreased. At the same time, woodland increased because of wood encroachment due to government policies and political decisions, which excluded human activities in the park, thereby improving wood regeneration. The decrease in woodland cover and increase in grassland, bare land, built-up, and farmland cover in the unprotected area was attributed to policies changes, population increase, cultural and economic changes. The intensification and modernization of agriculture, presence of the park and population increase, and climate change are causing more pressure on land, thereby causing the disappearance of wetlands, and to some extent, erosion causing bare lands, especially in hillslopes. The existing land dispute may further cause land use and land cover to change, thereby increasing further subdivisions and fragmentation, detrimental to land productivity. Therefore, the future sustainable land use in Sanga-Lake Mburo depends on understanding these patterns of LULCC and strengthening the technical capacity of land management institutions.

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