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Research Article

Land-use land cover changes and their relationship with population and climate in Western Uganda

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Abstract

Sustainable management of land and its ecosystem requires well-documented Land-use and Land Cover changes (LULCCs) that have occurred over time. The objective of this study was to document the LULCCs, determine their relationship with climate and population changes in Western Uganda, and provide evidence to support decision-making in this region. This study utilized satellite images for the years 1992, 2000, 2010, and 2020 obtained from the European Space Agency Climate Change Initiative (ESA CCI), climatic data from NASA, and population data from the Uganda Bureau of Statistics (UBoS). LULCCs and their influencers were characterized in the region, for the period 1992 to 2020. ArcGIS Pro Software Program was used to Filter time series data using Definition Query, while the scatterplot was employed to determine the relationship between changes in climate and population on LULCCs. Results indicate that LULC is dominated by agriculture (66.46%), followed by forests (16.22%), waterbodies (8.0%), grassland, shrubland, wetland, and urban areas at 6.11%, 2.63%, 0.49%, and 0.1%, respectively. From 1992 to 2020, the area under agriculture, forest and urban increased by 0.1%, 0.1%, and 0.08%, respectively, while grassland, wetland, and shrubland declined by 0.22%, 0.05%, and 0.01%, respectively. LULCCs for areas under wetland, grassland, and urban areas have a stronger relationship with precipitation and population growth. This information can be used by the decision-makers at the local, district, and national levels to better guide land-use practices aimed at sustainable land-use management for the current and future generations.

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Introduction

According to the World Population Prospects (2017), it is estimated that, with the current population projected to increase at the rate of 3% per annum, Uganda's population is likely to move past 100 million by the year 2050. This will constantly require an uninterrupted supply of food and livelihood from the inelastic land resources, most especially from the rural or peri-urban areas. Uganda has eight regions with distinct agroecological conditions and ten agroecological zones, which greatly have a bearing on the type and amount of food that is produced across the year for several generations (CIAT, 1999; Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), 2018; World Bank, 2019). Land-use land cover continues to be a major concern in the sustainable management of inelastic natural resources at the global, continental, and national scales (Xie et al., 2020; Bremer et al., 2021; Leal Filho et al., 2021; Olorunfemi et al., 2022). The degree of importance is augmented by the rate at which the perceptible drivers are causing threats to individual livelihoods at the micro-level, the GDP of the countries in question, and other likely consequences of climate change in the long run (Kizza et al., 2017).

Land-use land cover changes, according to numerous scholars, are driven by several factors, such as humans' quest for survival in a resource-constrained world (Luwa et al., 2021; Gillespie et al., 2022). These include population growth that has created an insatiable demand for essential needs like food, shelter, and health among others (Abdurahman et al., 2023). Climate change has also been cited by different scholars to be among the drivers of land-use land cover change, though it may sometimes be a primary consequence of human activity (Gillespie et al., 2022). There have been changes in the land-use land cover, now visible in the rate of urbanization, encroachment on protected areas like wetlands, national parks, and game reserves, deforestation, especially the natural forests, and reduction in the areas covered by grasslands (Kiggundu et al., 2018; Mwanjalolo et al., 2018). These effects of land-use land cover if not properly handled, may threaten the survival of future generations as they may result in significant reductions in the food supply and other livelihood sources to cater for the rapidly increasing populations and may also result in global warming with the associated long-term effects. Several studies have been carried out in Uganda, to present the land-use land cover changes that happened over a long period; however, these studies have majorly covered the following areas: urban settlements, protected areas like national parks and game reserves, wetland areas, drylands, rift valleys, and the geographical scope have not been at regional scale in Western Uganda (Bernard et al., 2010; Buyinza and Mugagga, 2010; Kizza et al., 2017; Muwanga et al., 2020; Lunyolo et al., 2021; Mulinde et al., 2022).

The Government of Uganda has policies that are implemented through different ministries, departments, and agencies, aimed at restoring degraded wetlands and forests (Ministry of Water and Environment, 2022). For example, people residing near the wetlands have been sensitized about alternative ways of sustainable use of these resources, such as the adoption of fish farming and paddy rice cultivation (World Bank, 2021). Uganda's National Vision 2040 with the theme, "A Transformed Ugandan Society from a Peasant to a Modern and Prosperous Country within 30 Years" aims at the exploitation of its resources gainfully and sustainably through increasing agricultural productivity and oil exploration, among other strategies (National Planning Authority, 2020). For these plans to be effectively implemented, they need to be guided by LULCCs and how they relate to population growth and climate change to maintain an ecologically balanced ecosystem that continuously offers diverse livelihoods to its population. Over the last two decades, there has been increased investment in Western Uganda, mainly after oil exploration began, with commercial production activities set to begin within this decade (Nuwagaba and Ukamba-muhiya, 2021; Twongyirwe et al., 2022). Additionally, Western Uganda has, on several occasions, experienced an influx of migrants from different parts of Uganda and neighbouring countries and hosts many refugees from the Great Lakes region (Ronald, 2022). This could be because of its strategic location, a long history of good climate, arable land, and numerous lakes on which fishing is one of the major economic activities.

Additionally, the Western region has the tallest mountains, numerous gazetted natural tropical forests, (the largest in Uganda), national parks, and game reserves (Uganda Bureau of Statistics, UBoS, 2022). This region is also known to produce numerous cash crops, including tea, coffee, and sugar cane, which are major contributors to Uganda's foreign exchange earnings, with animal production also thriving (UBoS, 2022). With all these features, coupled with climate change, population growth and the massive government investment in the region over the last 15 years, there have been tremendous changes in land-use and land cover. However, there is limited information on different land-use land covers, how these have changed over time, and whether these changes are influenced on the macro-level by population growth and climate change. This is an important foundation for planned sustainable development so that natural resources are not extinct at the expense of anthropogenic activities. Therefore, there is a need to document LULCCs, in this region, which is important to Uganda in terms of supporting livelihoods, oil production, tourism, and because the region accounts for about 35% of the total population of Uganda (National Environment Management Authority (NEMA), 2014; UBoS, 2020). It is against this background that this study determines the land-use land cover changes that have occurred in Western Uganda (1992-2020), and how population growth and climate change independently relate to the identified changes. This is justified in guiding policy recommendations geared towards sustainable use of land and the entire ecosystem while maintaining a constant supply of livelihoods.

Materials and Methods

Study area: Western Uganda

Western Uganda is currently made up of 35 districts and has an approximate land mass of 50,550.2 square kilometres (UBoS, 2021) (Figure 1). The Western region lies around latitude and longitude 0° N-02° N, 29.8°-31.02° E and -1° S -0° N, 29.7°-31.5° E (South) (Ngoma et al., 2021; Ogwang, and Ojara, 2022). A big portion of this area receives bimodal annual mean rainfall ranging between 1,000 mm and 1,800 mm and mean temperatures ranging between 15-29 degrees Celsius (Ogwang and Ojara, 2022). This climate has, over many years, been found to be favourable for producing food, cash crops, forest and forestry products, fishing, and rearing livestock. This region is known to produce Banana, coffee, beans, tea, ground nuts, millet, Peas, and horticultural crops, which are the major crops grown in Uganda (UBoS, 2021). There are variations in the production volumes of these agricultural products as one moves from one district to another due to changes in precipitation, temperature, and soil fertility levels, among other factors. This region falls under 03 agroecological zones (CIAT, 1999; MAAIF, 2018). It is currently estimated to be occupied by approximately 11.5 million people of which 70% are actively involved in agricultural and related activities (UBoS, 2021). This region has a mixture of farmers who are smallholder and medium to large-scale farmers, however, smallholder subsistence farmers constitute most of the farming households (FAO, 2021). This region has made significant strides in the expansion of land under both food and cash crops over thirty years, though the climate conditions are always very unpredictable by the population involved in the agricultural value chain (FAO, 2021). It can also be noted that the has been a proliferation of urban centers across this region, more especially with the creation of numerous Districts and Town Councils in the last decade. The policy on partitioning these districts was driven by the significant increase in the population and demand for service delivery as per the decentralization policy, among other issues.

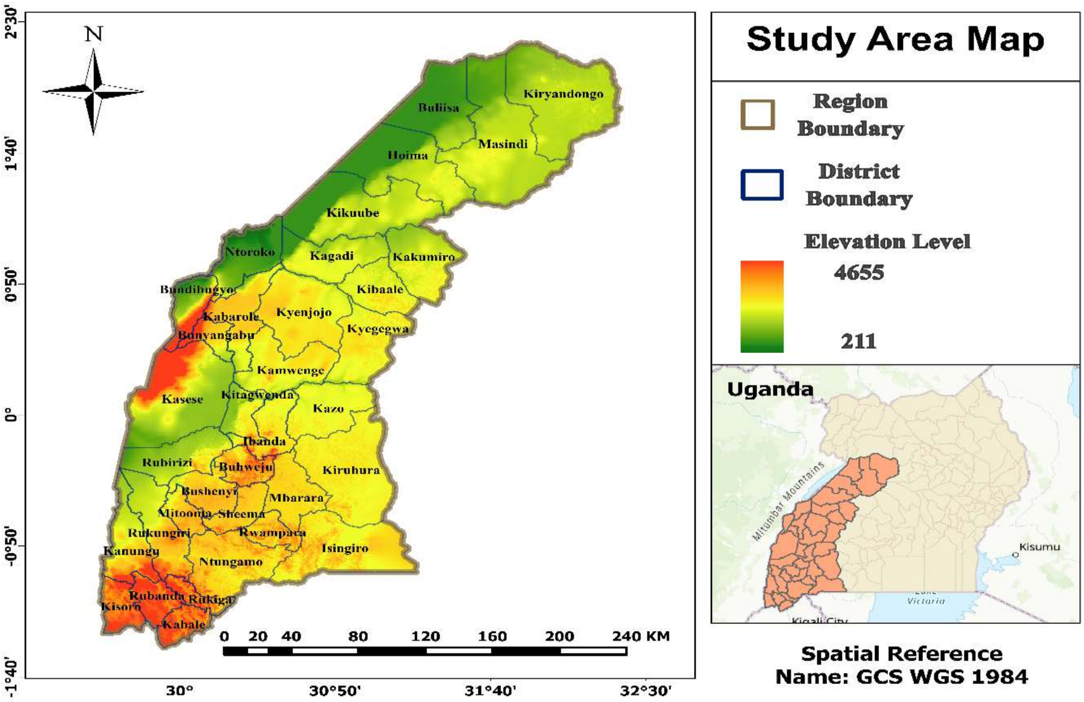

Figure 1. Map showing the study area.

Data sources

LULC data

LULC data, a time-series map of the surface of Earth from The European Space Agency Climate Change Initiative (ESA CCI) was developed by the United Nations (UN) Food and Agricultural Organization (FAO). The ESA CCI is classified into 36 land cover types. Land cover maps are a valuable resource for researchers studying Land Cover Change and its impacts on the environment. The maps are available for the years 1992-2020 and cover the entire globe. These classes include agriculture, forests, grasslands, urban areas, and other categories with a spatial resolution (300 m) (European Space Agency Climate Change Initiative (ESA), 2022). The LULCC data user guide that is used to process the images and maps is also available on the ESA CCI website.

Climatic data

Climatic data was used in this study to analyze the relationship between LULCC and climate and consists of annual temperature and rainfall data. This data was obtained from the National Aeronautics and Space Administration (NASA), Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (POWER) Project funded through the NASA Earth Science/Applied Science Program, Applied Sciences Program within the Earth Science Division of the Science Mission Directorate. This was accessed at https://power.larc.nasa.gov/data-access-viewer.

Population data

The population data used to analyze the relationship between land cover change was obtained from UBoS (1990, 2000, 2014, 2020) (https://www.ubos.org/). By law, UBoS, a government entity, carries out a national census every ten years, and the results from the exercise are uploaded on its website for use by public entities. However, for some reason, in the year 2010, this exercise was not carried out, thus resulting in missing data. Thus, the initially planned decadal population interval could not be maintained for this study, as there was no data, and the nearest available data was for the year 2014.

Data analysis

Land-use Land Cover (LULC)

The European Space Agency (ESA) provides a time series of land-use/land cover (LULC) data that can be used to monitor changes in land cover over time. The data is available in a raster format and contains 36 different land cover classes. Definition Queries were used in ArcGIS Pro Software, to filter data so that only a subset of the features appears in the layer. The data layer was filtered to show only the features that meet the criteria in the Definition Query to specify the intended year. Definition Queries affect not only what is visualized on the map, but also which features appear in the layer's attribute table and can be selected, labelled, identified, and processed by geoprocessing tools. The data contains more detailed classes, about 36, so it was converted to a vector, and some classes merged based on the user guide of the data mentioned above and calculated area and percentage per class.

Rainfall and temperature

To examine the variability and patterns of rainfall and temperature spatiotemporal using geospatial techniques. The point data of rainfall and temperature was clipped to the shape file of the study area boundary. Thereafter, interpolation using Inverse Distance Weight (IDW) was done to generate values of climate data for the unsampled or unmeasured places. IDW assumes that each measured point has a local influence that diminishes with distance. The shape file of the study area was further used to delineate the raster format of each of the climate data. Total precipitation, and temperature (min–max), after which spatial maps were generated over a ten-year interval.

Population

This data was downloaded from the Uganda Bureau of Statistics (https://www.ubos.org/) website in an Excel format that contained all the districts in Uganda for each of the census periods corresponding to the scope of this study. This was filtered to only Western, Uganda and then data was summed up for each of the districts in the region of interest per each of the four time periods. This data is available for public use with acknowledgement of this source.

Determination of the relationship between LULCC, climate, and population changes

LULCC, climate and population change data was transferred to Excel and using the scatterplots for each of the LULCC per class against temperature, precipitation, and population. With the scatterplots, straight lines curves were plotted, and trendlines were formatted into exponential form, display of equations and R^2 value were added per chart for each of the LULCC (Mandal et al., 2019).

Results and Discussion

Visualization of LULCCs for the period 1992-2020

Table 1 presents a summary of the seven LULCCs for the period 1992 to 2020 in terms of square kilometres and associated percentages based on the seven LULC classes that are extracted from Western, Uganda. The majority of LULC studies previously done in Uganda indicate four major LULCs and exclude water, which commands a large area (3rd) in the Western region (Luwa et al., 2021). From the year 1992, the percentage of the total study area was dominated by Agriculture, covering 66.46%, followed by forests (16.22%), waterbodies (8.0%), and then grassland, shrubland, wetland, and urban areas at 6.11%, 2.63%, 0.49%, 0.10% respectively (Table 1 and Figure 2). There is an observed change for all LULCC classes except waterbodies from the year 1992 until 2020.

Table 1. LULCCs from 1992 to 2020.

Years	**1992**		**2000**		**2010**		**2020**	
LULC (Area km²/%)	**km²**	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**
Water	4,190.940	8.000	4,193.280	8.005	4,191.300	8.014	4,190.490	7.999
Wetland	282.780	0.540	267.120	0.510	264.960	0.507	258.390	0.493
Grassland	3,315.510	6.329	3,264.030	6.231	3,247.920	6.210	3,199.050	6.106
Agriculture	34,765.898	66.361	35,186.102	67.174	34,991.000	66.901	34,815.602	66.456
Shrubland	1,379.790	2.634	1,345.140	2.568	1,327.500	2.538	1,375.940	2.626
Forest	8,446.140	16.122	8,112.600	15.488	8,245.890	15.766	8,497.170	16.219
Urban Areas	8.370	0.016	12.150	0.023	34.120	0.065	52.290	0.100
Total	**52,389.428**	**100.0**	**52,380.42**	**100.0**	**52,302.689**	**100.00**	**52,388.932**	**100.00**

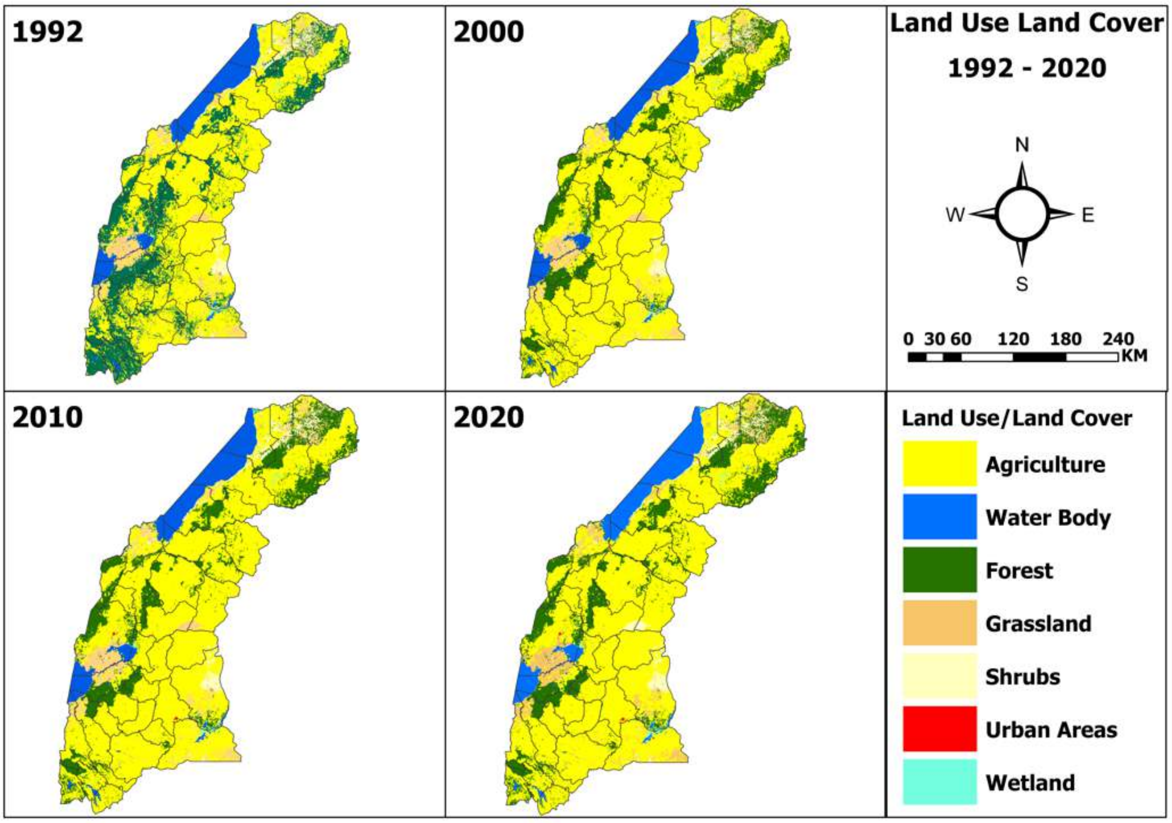

Figure 2. Land-use land cover change maps for 1992, 2000, 2010, and 2020.

Throughout three decades, the area under agriculture increased by 0.1%, though it had initially increased by 0.813% by the year 2000. This percentage increase in land under agriculture is consistent with the previous study by Bernard et al. (2010), on the dynamics of land-use/cover trends in Kanungu district, South-western Uganda, for 1975-1999, which estimated the increase in the area under agriculture. This could be due to the increase in the demand for food, which comes primarily from farming activities (Muwanga et al., 2020). Additionally, the increase in the area under agriculture could be because of the government policy on tea and coffee expansion through the National Agricultural Advisory Services (NAADS), whereby for the last two decades, millions of tea and coffee seedlings have been freely given to farmers in this region, which is predominantly a coffee and tea growing region (Ministry of Agriculture, Animal Industry and Fisheries, 2020).

The forest area increased by 0.1%, which agrees with the statistics from (UBoS, 2022); however, it contradicts the studies by Kizza et al. (2017), Kiggundu et al. (2018), and Omeno et al. (2021) that indicate a decline in forest area in Uganda. The increase in the area under the forest could be due to the forest restoration program under the National Forestry Authority, whereby several hectares of public land have been leased to private individuals to plant eucalyptus trees. This has been massively implemented mainly in the last decade, as reported in the national statistics (UBoS, 2022). According to the World Bank Report (2021), Uganda has the highest forest loss at 2.6%, this is because it's the main source of firewood in the rural communities. Additionally, Mawa et al. (2022) in their study about conservation outcomes of collaborative forest management in a medium altitude semideciduous forest in mid-western Uganda report about declining forest species in the protected forests due to charcoal burning. Grassland has declined by 0.22%, and the trend is steadily declining. Waterbodies remained at 0.8% in the twenty years. The area under shrubland has also declined by 0.01%, though there was an initial marked drop in 2000 and 2010, while some small recoveries were realized in the year 2020 (Figure 3, Figure 4, and Table 1). The area under wetlands has declined by 0.05%, and this has been consistently on a downward trend since the year 1992; this could be explained by increased levels of encroachment by human activities, majorly for farming (Muwanga et al., 2020). In all the LULC changes, it is the Urban Areas that increased four times its original size to 0.1% of the total land area, and this has been consistent for the last three decades. This agrees with the studies by (Bunyangha et al., 2021; Omeno et al., 2021), which assert that farmland and built-up areas will continue to increase in all the villages, while the areas under forest will continue to decrease.

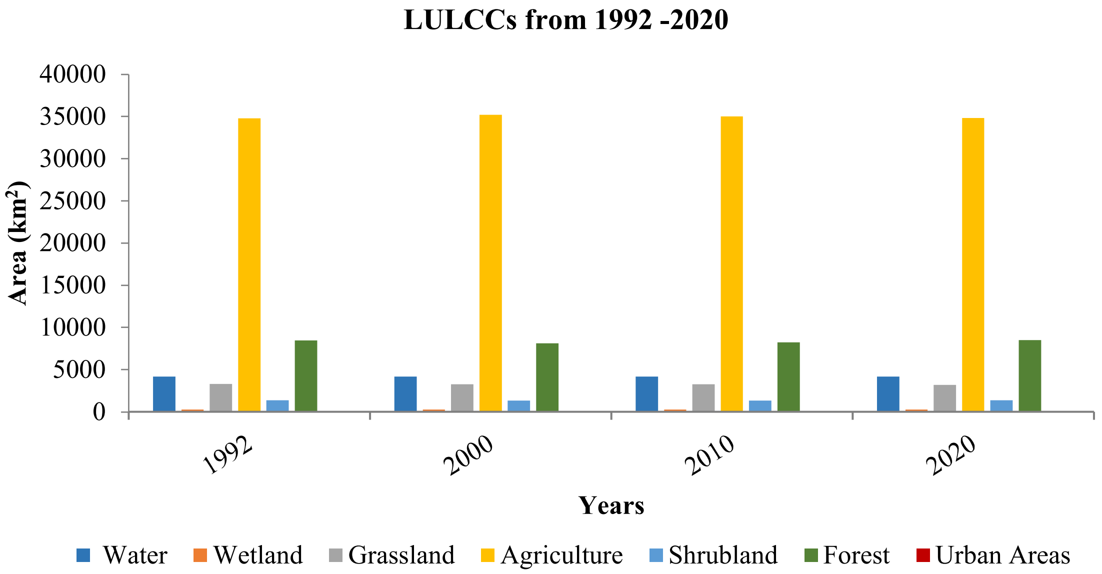

Figure 3. Graphical representation of LULCCs for the years 1992, 2000, 2010, and 2020.

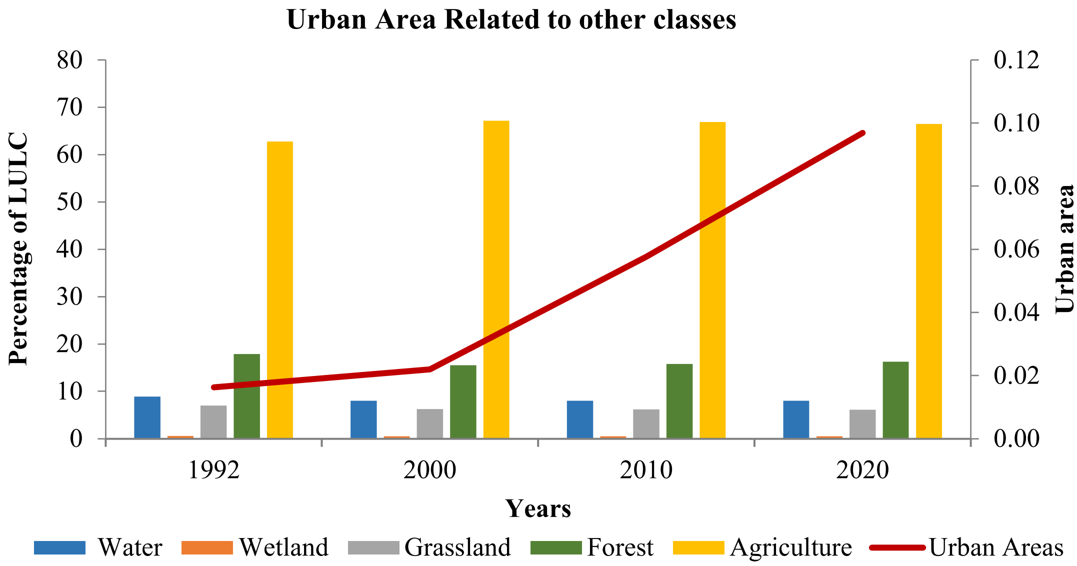

Figure 4. Graphical representation of LULCCs under Urban Areas compared other four classes.

Spatial variation in mean annual precipitation

Precipitation in Western Uganda is generally received in varying volumes from one district to another and from one part of the region to another. It is usually received in a bimodal pattern, with the May-August and December-March known to be the dry months, receiving the least precipitation. There is an observed steady increase in annual precipitation, with the year 2020 showing the highest precipitation (Figure 5). However, between the years 1998 and 2018, the general annual average precipitation ranged between 600 mm to 1,200 mm. The annual precipitation recorded in each area is dependent on the nearness or presence of certain land-use land cover features that may include mountains (Rwenzori and Mahubura), forests (Karinju, Budongo and Bwindi and others), and lakes (George, Edward, Bunyoyi, and others). In Figure 6, it is observed that in the year 1992, three quarters (lying in the northern part of the study area) received mean precipitation in the ranges of 1,298-1,550 mm, while the other quarter received volumes between 1,086-1,260 mm. There is a drastic reduction within the following 10 years (in the year 2000), whereby the northern and a big part of the southern part received a considerable reduction in the annual precipitation. In Figure 6, about three-quarters received mean rainfall between 775-921 mm, and only a quarter received amounts ranging between 947-1,223 mm.

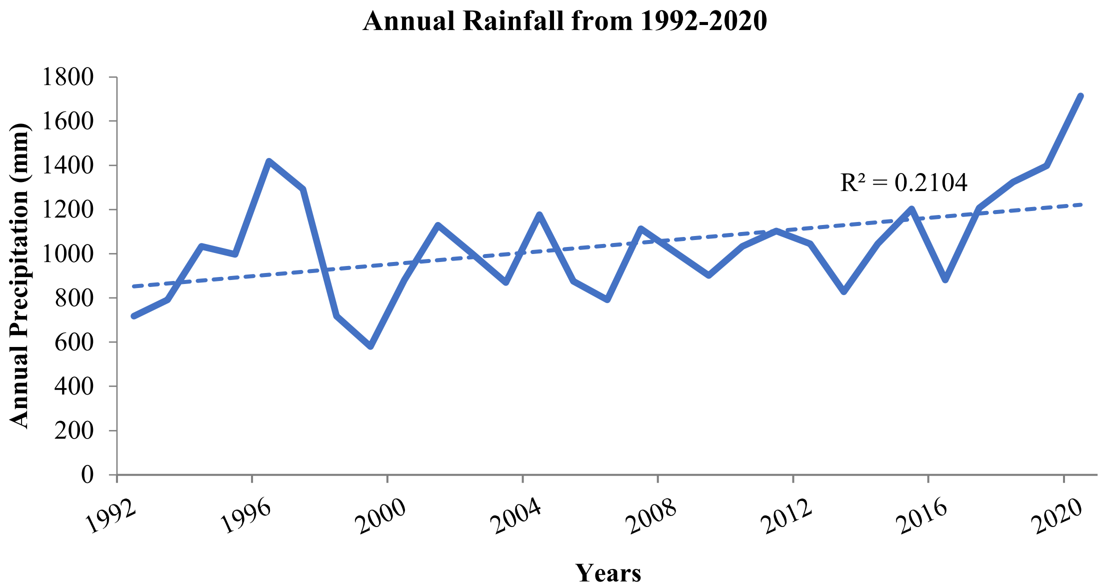

Figure 5. Mean annual change in precipitation from 1992-2020

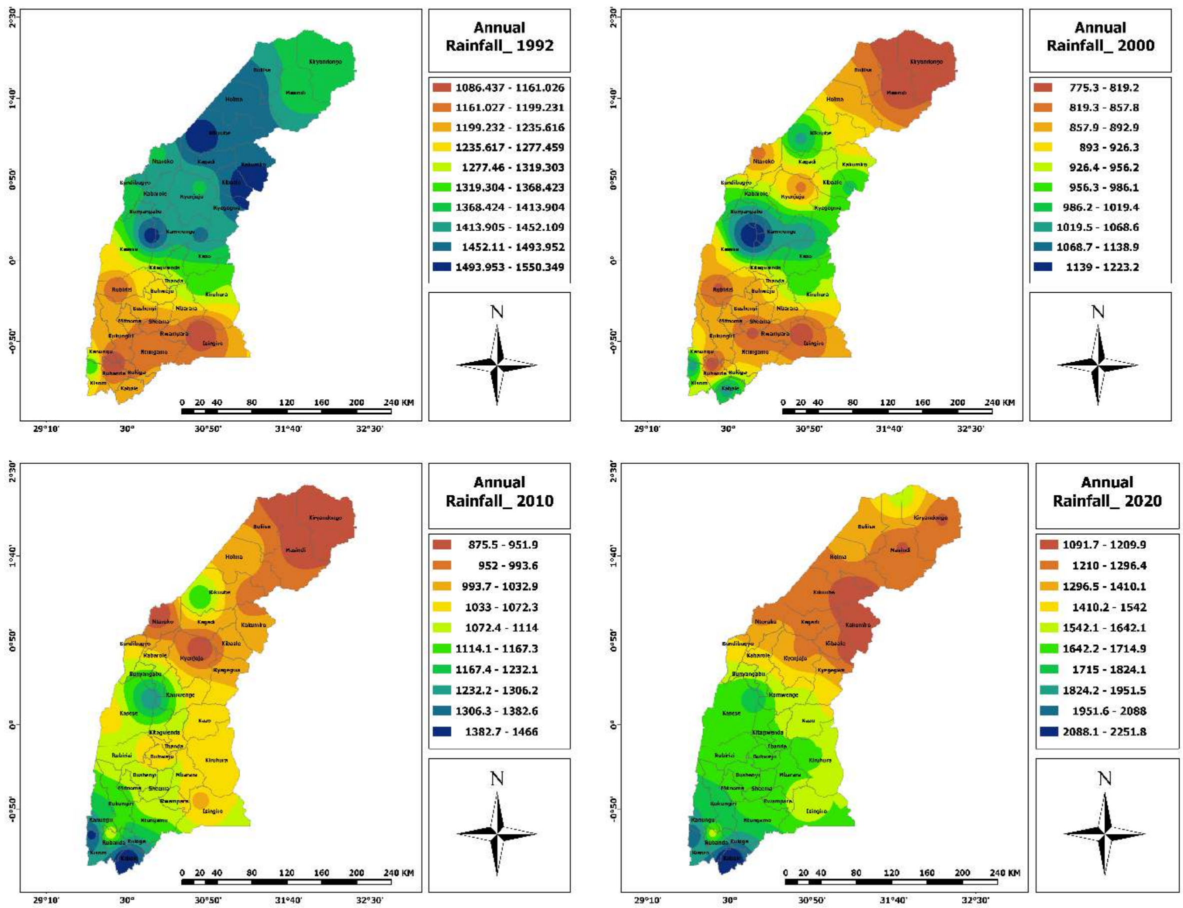

Figure 6. Annual rainfall distribution for the years 1992 to 2020.

The annual mean rainfall received in the year 2010 began to rise as compared to the year 2000, with the region divided into two halves, the bigger portion of the southern part received precipitation ranging between 1,100-1,466 mm, while the other upper half received a mean of between 875-1,069 mm. Comparing the two decades in Figures 5 and 6 (2010 and 2020), there's a visible increase in the areas receiving mean annual precipitation greater than 1,100 mm, and this is observed more in the southern part of the study area and fades away as one moves to the northern part. The border districts of Kisoro, Kabale, Rukiga, and Rubanda received the highest precipitation. This agrees with the study by Ngoma et al. (2021) on assessing current and future spatiotemporal precipitation and trends over Uganda and East Africa.

Spatial variation in terms of temperature for the period 1992-2020

There is considerable variation in the maximum and minimum temperatures throughout the thirty years (Figure 7). Throughout the 30 years, the maximum temperature had increased from about 34°C to 39°C from the year 1992 to 2007, after which it declined to about 27°C (2007-2010) and after a steady rise from 2010 until 2019, with the highest in 2019 at 39°C (Figure 8). This is in agreement with the report from the national meteorological authority about the hottest years in the last three decades (Ogwang and Ojara, 2022).

In general, areas in the northern part of the study area, which lies above the equator, are hotter in the period 1992-2020 as compared to the rest of the region, more especially, the southern part of the region. The minimum temperatures rotated between a mean of 10°C and 16°C over the three decades. From the state of the Ugandan climate, the five warmest years in the western and Western are 2009, 2016, 2017, and 2021, respectively (Ogwang and Ojara, 2022). Living organisms' (Flora and Fauna) physiological mechanisms are influenced by the heat waves, and for some, their normal functioning may be impaired. For example, some plants may easily succumb to very high temperatures, as there will be excessive water loss through the stomata. For this case, and in addition to other factors some farmers have encroached on the wetlands where, even with increased temperature and evaporation, plants can easily get a reliable water supply.

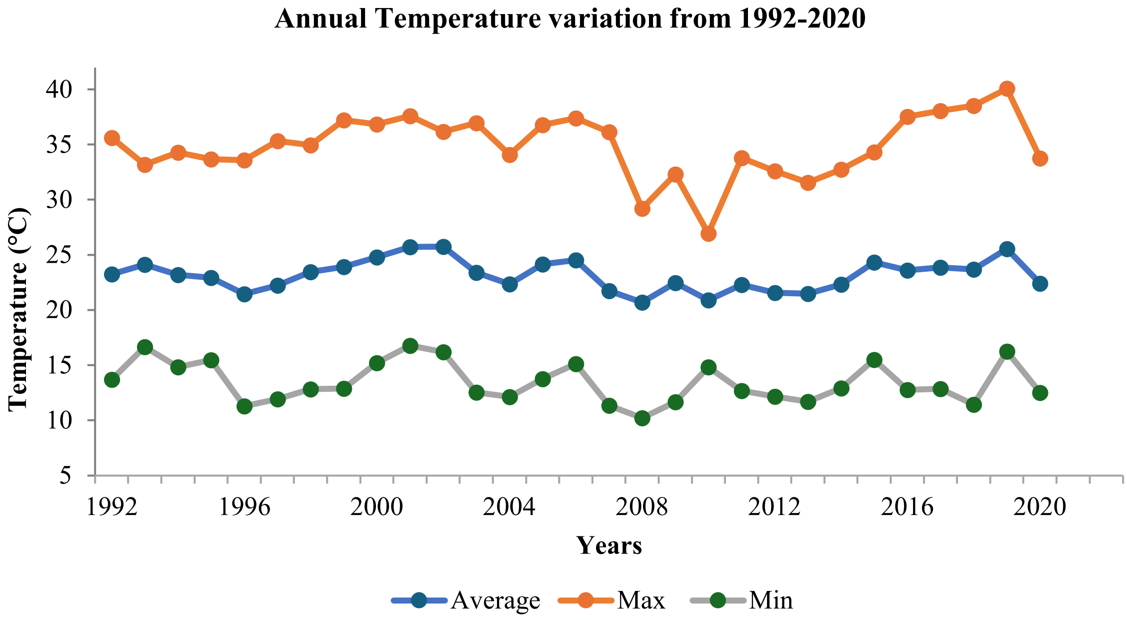

Figure 7. Annual minimum, mean and maximum temperatures 1992-2020.

Determination of the relationship between climate and population on LULCCs

To determine the relationship between LULCCs, climate change, and population growth, a scatterplot and exponential trendline analysis using the Excel scatterplot chart method were used. This method served to unveil the link between LULCCs and their potential relationship with climate and population. A study by Mandal et al. (2019) used scatterplots with trendlines and equations in the visualization of the relationship between urbanization and growth trends. The determination of whether the relationship and trend were reliable was based on the R^2 values. The nearer R^2 is to 1, the better the trendline fits the data in question, and thus the relationship exists. Therefore, the climate and temperature variables whose R^2 was greater than 0.5 were potentially related to the specific LULCCs in the plot. From Table 2, it is ascertained that there is a positive relationship between population growth and LULCCs for grassland, wetland, and urban areas. Population growth affects LULCCs in the study area through an increase in the demand for settlement and source of livelihood, which can lead to the conversion of some of the different land covers as years go by. For example, some percentage of the areas initially occupied by wetlands and grasslands may be converted into agricultural land or urban areas (settlement, roads, and other infrastructure) (Cooper, 2018; Luwa et al., 2021). Since land is inelastic, if this relationship exists, then LULC Changes may require proper planning in order not to affect the availability and quality of natural resources, such as soil, water, and biodiversity, which can have implications for human well-being in the long run (Onyutha et al., 2021). Table 2 indicates that LULCCs under Urban, Grassland, and Wetland areas have a positive relationship with Population growth for the period 1992, 2002, 2014, and 2020. There have been reported cases of wetland degradation, mainly for settlement and farming operations by the Ugandan government across the country to drive people out of the wetlands (Government of Uganda Report, 2016). This study agrees with that of Akello et al. (2016) on land-use/cover change and perceived watershed status in Eastern Uganda. In their study, they assert that as the population grows, there will be higher cases of Wetlands degradation.

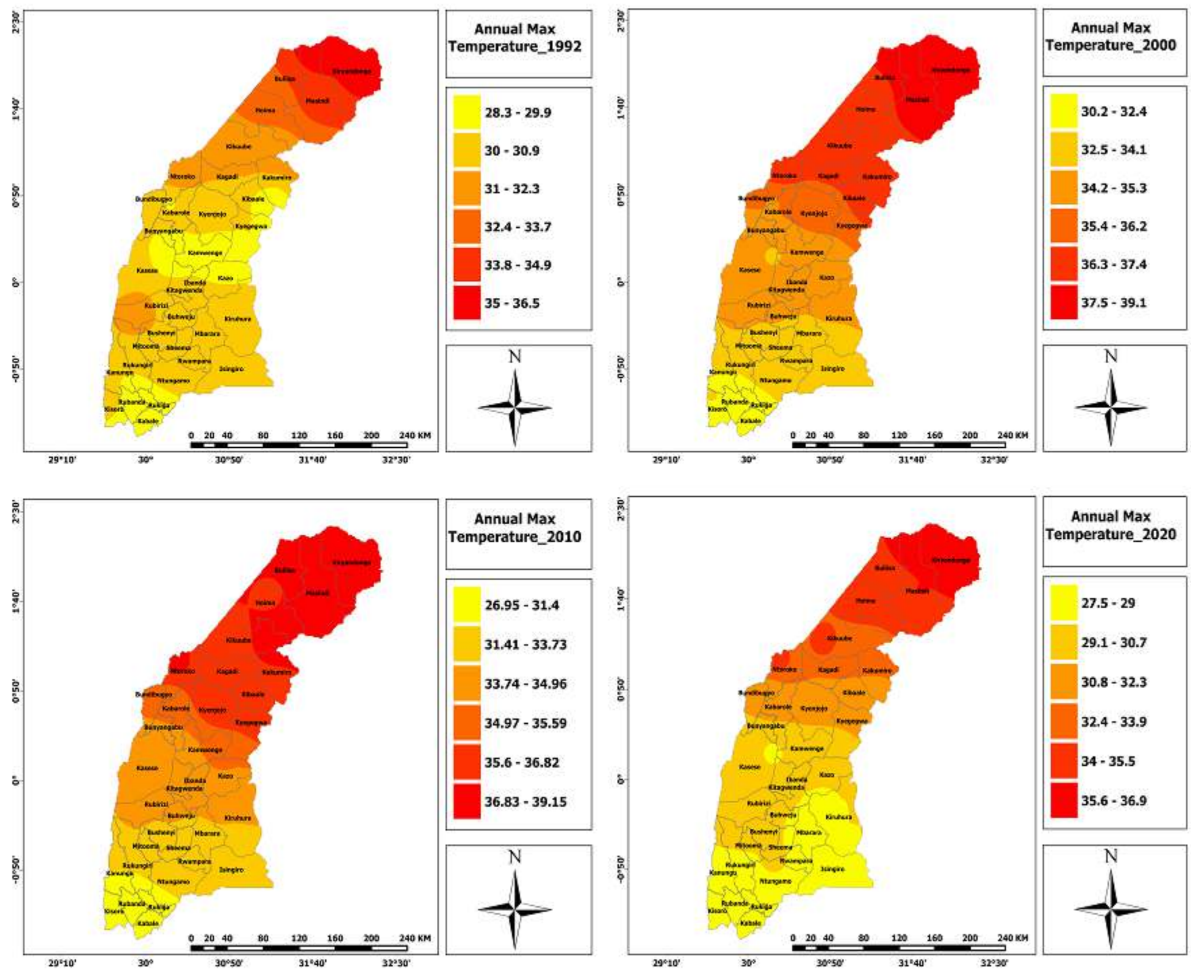

Figure 8. Temperature variation maps for the years 1992, 2000, 2010, and 2020.

Table 2. The relationship between changes in LULC and population growth.

Year	1990	2002	2014	2020	Model Fit (R^2)
Population	4,547,687	6,298,075	8,874,860	10,453,720	
LULCCs					
Water	4,190.940	4,193.280	4,191.300	4,190.490	0.149
Wetland	282.780	267.120	264.960	258.390	0.854
Grassland	3,315.510	3,264.030	3,247.920	3,199.050	0.927
Agriculture	34,765.898	35,186.102	34,991.000	34,815.602	0.003
Shrubland	1,379.790	1,345.140	1,327.500	1,375.940	0.037
Forest	8,446.140	8,112.600	8,245.890	8,497.170	0.045
Urban Areas	8.370	12.150	34.120	52.290	0.993

There is no relationship between each of the LULCCs and variation in maximum temperature (Table 3). This could be because the visible changes in terms of square kilometres are among wetland, grassland, agricultural shrubland, and forest, which contribute to the albedo. Therefore, temperature variation could be a result of climatic changes beyond the area under study. This contradicts the study by Tan et al. (2020) on the spatial relationship between land-use/land-cover change and land surface temperature in the Dongting Lake area, China, which reported a relationship between LULCC and land surface temperature.

Table 3. The relationship between LULCCs and mean maximum temperature changes.

Year	**1992**	**2000**	**2010**	**2020**	**Model Fit (R^2)**
Temperature (ºC)	35.62	36.84	26.94	33.75	
LULCCs					
Water	4,190.940	4,193.280	4,191.300	4,190.490	0.133
Wetland	282.780	267.120	264.960	258.390	0.116
Grassland	3,315.510	3,264.030	3,247.920	3,199.050	0.095
Agriculture	34,765.898	35,186.102	34,991.000	34,815.602	0.001
Shrubland	1,379.790	1,345.140	1,327.500	1,375.940	0.370
Forest	8,446.140	8,112.600	8,245.890	8,497.170	0.002
Urban Areas	8.370	12.150	34.120	52.290	0.241

There is a relationship between annual precipitation and LULCCs in wetlands, grasslands, and urban areas (Table 4). Wetlands and shrublands show a relationship with precipitation, through evapotranspiration and cloud formation in the rain formation cycle as vegetation through the biochemical processes. Additionally, LULCCs in urban areas show a relationship with precipitation. This agrees with the review report by Li et al. (2020) on the Relationship of surface urban heat islands with air temperature and precipitation in large global cities, in which they assert that urbanization promotes annual precipitation.

Table 4. The relationship between LULCCs and change in mean annual precipitation.

Year	**1992**	**2000**	**2010**	**2020**	**Model Fit (R^2)**
Precipitation	717.190	914.563	1,069.502	1520.005	
LULCCs					
Water	4,190.940	4,193.280	4,191.300	4,190.490	0.2605
Wetland	282.780	267.120	264.960	258.390	0.7768
Grassland	3,315.510	3,264.030	3,247.920	3,199.050	0.9538
Agriculture	34,765.898	35,186.102	34,991.000	34,815.602	0.0683
Shrubland	1,379.790	1,345.140	1,327.500	1,375.940	0.0512
Forest	8,446.140	8,112.600	8,245.890	8,497.170	0.2369
Urban Areas	8.370	12.150	34.120	52.290	0.9378

Conclusions

Analysis of LULC reveals that by the year 2020, the study area was dominated by agriculture, covering 66.46%, followed by forests (16.22%), waterbodies (8.0%), and then grassland, shrubland, wetland, and urban areas at 6.11%, 2.63%, 0.49%, 0.1% respectively. Consequently, there have been changes in the LULC; however, these changes have not caused bigger shifts and transformations from one LULC to another. It also found that significant changes have occurred in agriculture, urban areas, shrubland, grassland, and wetland land-use classes. The area under agriculture, forests, and urban areas increased by 0.1%, 0.1%, and 0.08%, respectively, while grassland, shrubland and wetlands declined by 0.22%, 0.01%, and 0.05% respectively. The findings highlight that LULCCs under wetland, grassland, and urban areas show a relationship between Precipitation change and population growth. Future studies can also explore how the ongoing oil exploration activities, socio-economic factors, prevailing policies, and construction of the proposed mapped pipeline in this region are going to impact the LULC classes in this region. Also, there is a need to study the relationships between LULC change and soil quality or soil fertility, which in turn affects the socio-economic conditions of the communities in this region.

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