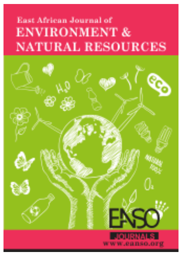

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Original Article

Interrogating the Impact of Land Use/Land Cover Dynamics in Mbarara City in Southwestern Uganda

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ABSTRACT

The urbanization in Mbarara City Southwestern Uganda has increased the number of built-up and small-scale agricultural areas thus escalating pressure on the grassland and woodlot areas hence influencing land fragmentation and slum development. In this study, we focused on land use/land cover dynamics. This helped us to identify land uses that reduce grassland areas, which increases land fragmentation, and slum development. Presumably, the land uses in the area included built-up areas, grassland, small-scale agriculture, and woodlots. Built-up, grassland, and small-scale agriculture were vital for our analysis. We employed remote sensing techniques (Supervised-Maximum Likelihood Classifier) with two cloud-free high-resolution images of 2010 and 2022 in mapping spatial-temporal patterns in built-up, grassland, and small-scale agriculture. Our results evidenced that built-up area increased by (5.14%), grassland declined by (7.1%), small-scale agriculture increased by (2.62%), and woodlots reduced by (0.73%) between 2010 to 2022 and the accuracy assessment for the image classification was (83%). Our study found that an increase in built-up areas and small-scale agriculture led to the decline of the grassland and woodlot areas between 2010 to 2022 with a statistically significant difference (p = 0.03). There was also a strong positive correlation (r = 0.97) between land use/land cover types in 2010 and 2022. Our study recommends that Mbarara City Authority should put strict laws and regulations governing the minimum size of land required during sub-division to avoid land fragmentation which results in increased slum development. Increased land fragmentation may have an intense impact on important ecosystems such as grasslands.

APA CITATION

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INTRODUCTION

Land use/land cover changes within Sub-Saharan Africa have been evidenced to have an impact on grazing and small-scale agriculture which is mainly commercial and subsistence in nature (Lambin *et al.*, 2001). Anthropogenic activities have been indicated as a vital reason for the global land dynamic processes (Pielke Sr *et al.*, 2011; Behera, 2012; Nyamugama & Kakembo, 2015). Likewise, the built-up area is one land use that is prominent in most cities around the globe and is characterized by increasing urbanization (Kundu & Pandey, 2020). In 1950, global urbanization was 0.75 billion people and it escalated in 2018 to 4.22 billion people as documented by Kundu and Pandey, 2020).

Apart from urbanization, the increased population has also been documented and evidenced as a major factor behind land use changes in urban areas (Gondwe *et al.*, 2021). According to Fonji and Taff 2014; Baig *et al.* (2022), land use changes are highly interconnected with population growth in an area. Such increasing population growth has been noted in several cities in Africa (Burton, 2017). According to (OECD/UN ECA/AfDB, 2022), urbanization has challenges in African cities such as improper planning of different land uses.

Furthermore, improper planning can lead to the destruction of important things such as grazing areas and encroachment on agricultural land. Other challenges of urbanization include increased food insecurity in the urban poor population which results in competition for limited food sources (Aubry *et al.*, 2010). In Uganda, for example, the Urban cities are still operating in an ad hock way which hinders proper planning of the activities (Mukwaya *et al.*, 2010). Although the main focus of urbanization is to improve economic progress and poverty lessening (United Nations, 2018), in Uganda, it has promoted slums and unplanned settlements hence leading to the degradation of important ecosystems such as rangelands which support cattle rearing (Mbabazi & Atukunda, 2020). The creation of new cities in Uganda following the presidential directive and approval by Parliament in July 2020 has attracted many people in towns hence causing urbanization (Uganda-Government, 2020).

Generally, the increasing population at 3.4 percent every year in Uganda can well explain the reasons behind urban sprawl (Josephat, 2018). For example, the increase in the urban population in Mbarara City in southwestern Uganda has called for more settlements and built-up areas as well as an increase in food demand because of the high population (195,013 people) as evidenced by (Twesigye *et al.*, 2022). This, therefore, has forced people to start sub-diving of the available land (grassland and cutting banana plantations) to expand on the land due to urbanization. In a long run, clearing grazing

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land and banana plantations in an unplanned manner has exacerbated land fragmentation in Mbarara City. More so, the destruction of important ecosystems such as grasslands has an impact on climate change in an area as evidenced by (Nuwagira & Yasin, 2022). Surprisingly, any impact on any ecosystem such as grassland and woodlots results from the collaboration between human beings and the environment (Pielke Sr *et al.*, 2011; Matsa *et al.*, 2020).

According to Mwesigye and Barungi (2021), land fragmentation in Sub-Saharan Africa and East Africa at large is very rampant. It involves the segregation of land into small parcels to achieve a particular function (York *et al.*, 2011). In Uganda particularly, it has been seen within the Kigezi highlands which resulted in food insecurity and land tenure issues (Carswell, 2002; Bamwerinde *et al.*, 2006; Kinyata & Abiodun, 2020). Land fragmentation has also been iconic in other parts of Uganda such as in the Kyenjojo district where the land was subdivided into small fragments hence causing food insecurity (Uganda-Radio-Network, 2015).

However, in Mbarara City, grazing land and small-scale agricultural land especially in Katete, Kakiika, and Kakoba divisions have been converted and fragmented into unplanned residential houses thus leading to the development of slums. The conversion of small-scale agricultural land into built-up and residential areas due to city urbanization also can increase food insecurity levels and poverty among the urban poor dwellers. Evidence by Nseka *et al.* (2022), an increase in built-up and residential areas in the Rwizi Catchment, has led to the decline in the small-scale agricultural land within Mbarara City.

Several studies have been conducted in the Mbarara district on land use/land cover changes (Brian, 2016; Uwizeye, 2021; Immaculate, 2022). However, the impact of land use changes (built-up and residential area expansion) on grazing and small-scale agricultural land within Mbarara City has not been researched and thus lacks empirical evidence. Land use/land cover mapping is vital in future land planning and management (Ayele *et al.*, 2018). In addition, no study has been done to document the influence of urbanization on the fragmentation of land within Mbarara City in southwestern Uganda. Land use/land cover mapping is very significant in the proper planning of urban areas such establishment of new cities (Liping *et al.*, 2018; Gondwe, Schulz, *et al.*, 2021).

The main aim of this study was to use Geographic Information System and Remote Sensing techniques to determine the impact of land use changes in Mbarara City. This was accomplished through determination of land use and landcover dynamics and establishment of the general overview of land fragmentation, and slum development of Mbarara City.

MATERIALS AND METHODS

Study Area

Mbarara City is located in southwestern Uganda (Bahati *et al.*, 2022). It is made up of Kamukuzi Division, Kakoba Division, Biharwe Division, Nyamitanga Division, Nyakayojo Division, and Kakiika Division**.** It lies at latitude 0°36'23.01"S and longitude 30°39'52.89"E, neighbors Isingiro district to the south, Rwampara district to the west, Kiruhura district to the west, and Ibanda district to the north *(Figure 1)*. The city has an estimated population of 195,013 people (Uganda Bureau of Statistics, 2016), with a distance of 168 miles by road from Kampala the Capital City of Uganda (Tumwesigye *et al.*, 2021; Kiprotich, 2022). The city is located in gentle to hilly areas with 1432 m.a.s.l separated by short, small, and shallow valleys and a parent rock made up of granitoid rocks, gneisses, mudstones, phyllites, and shales (UNRA, 2010).

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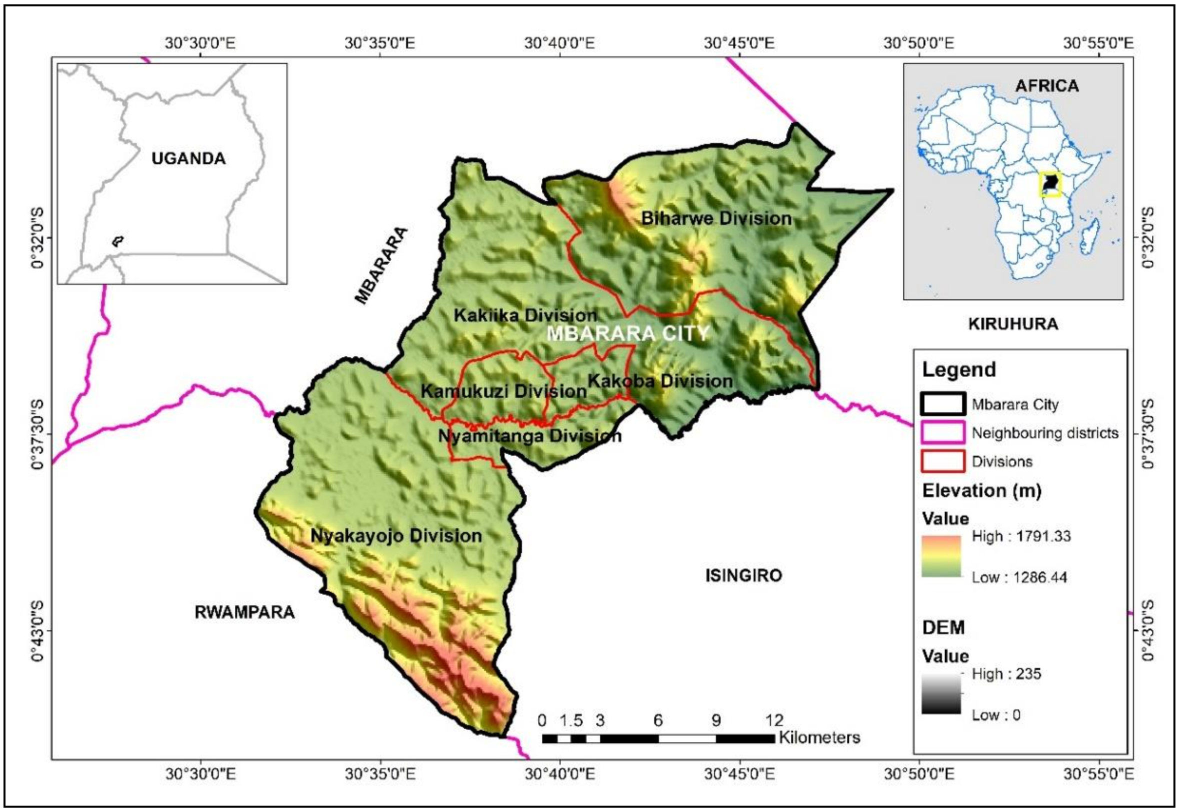
Figure 1: Location of the study area (Source; Produced by the authors using Arc GIS Version 10.8)



Data Collection

Geographic Information System data such as administrative boundaries (district, and sub-counties) were obtained from the Uganda Bureau of Statistics (UBOS) website (https://www.ubos.org). while the Digital Elevation Model (DEM) and hill shade were acquired from the Alaska Facility website (https://asf.alaska.edu/). The satellite images were obtained using Landsat 5 and Sentinel 2 satellites *(Table 1)* from the Earth Explorer website (https://earthexplorer.usgs.gov/), as well the United States Geological Survey (USGS) provides satellite images freely (Wulder *et al.*, 2016). The satellite images that were downloaded from these high-resolution images were taken from the driest months of the year to avoid the issues of cloud cover during image processing as recommended by (Twongyirwe *et al.*, 2015).

Table 1: Satellite image particulars

Date	Satellite	Path/Row	Resolution (m)	Cloud cover %
5/12/2010	Landsat 5	172/060	30	Less than 10
5/25/2022	Sentinel-2	172/060	20	Less than 10

Data Analysis

The data was analysed using ArcGIS version 10.8 to detect land use/land cover changes. Standard image classification procedures were used in the analysis of the land use/land cover types (Khatami *et al.,* 2016; Ma *et al.,* 2017; Costa *et al.,* 2018; Yousefi *et al.,* 2022). Pre-classification involved band stacking and image cleaning (brightness, transparency, and contrast) (Kazemi *et al.,* 2011; Saing *et al.,* 2021). Followed by image classification which involved supervised image

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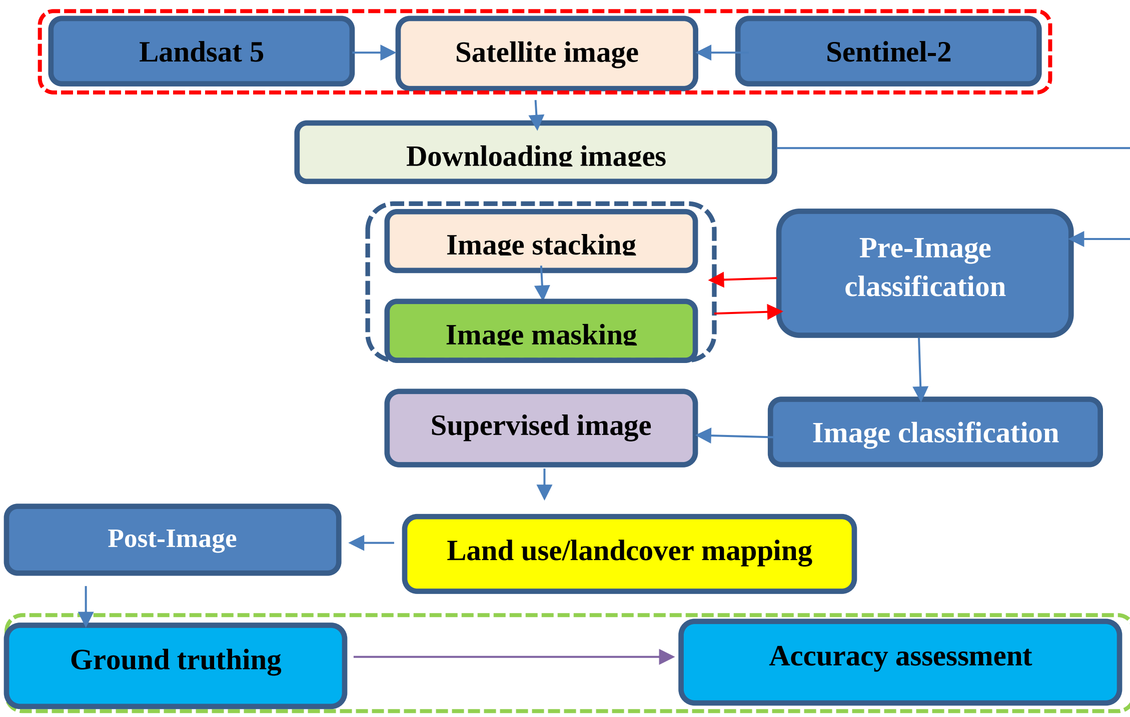
classification with the help of the Maximum Likelihood Classifier where training signatures for different land use/land cover types were created to come up with spectral signatures for each land use type following recommendations by Nangendo *et al.* (2007). Post-classification involved ground truthing and accuracy assessment for land use/land cover types (Suir *et al.*, 2021; Mabrouk *et al.*, 2022). We have a vital familiarity with Mbarara City following our experience in the area. We are, therefore, sure that our classification was very accurate following the accuracy assessment results.

Special Package for Scientists (SPSS) was used to determine the correlation between land use/land cover types between 2010 and 2022, and Microsoft Excel version 2016 was used to develop the graphs.

Figure 2: Flow chart showing the data sources and land use/land cover mapping



Land Use/Land Cover Dynamic Mapping

The results from the land use/land cover type analysis evidenced that the coverage of the built-up area in 2010 was less as compared to the built-up area in 2022 *(Figure 3)*. The average increment in the built-up area between 2010 and 2022 was (5.14%) which is well explained by *(Table 2)* Grassland reduced in the following years from 2010 to 2022 *(Table 2)* thus recording an annual decline of (7.03%). Small-scale agriculture registered an increment in the size of land from 2010 to 2022 *(Figure 2)*. In addition, over 12 years, small-scale agriculture has recorded an increment of only 2.62%. The land use/land cover maps also evidence that the coverage of woodlot was high in 2010 as compared to 2022 *(Figure 2)*. Further, this can be well elaborated by the statistics in *(Table 2)*. The land use/land cover maps can also explain well the fragmentation of grassland and small-scale agricultural land mostly observed in 2022 *(Figure 2)*. The results of Figure 2 also explain why there is an increasing slum development within Mbarara City. The general overview of Mbarara City evidenced the impact of the increase of built-up

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areas, the issue of land fragmentation, and the formation of slums in Mbarara City *(Figure 4)*.

Figure 3: Land use/land cover maps for Mbarara City. a) is 2010, and b) is 2022

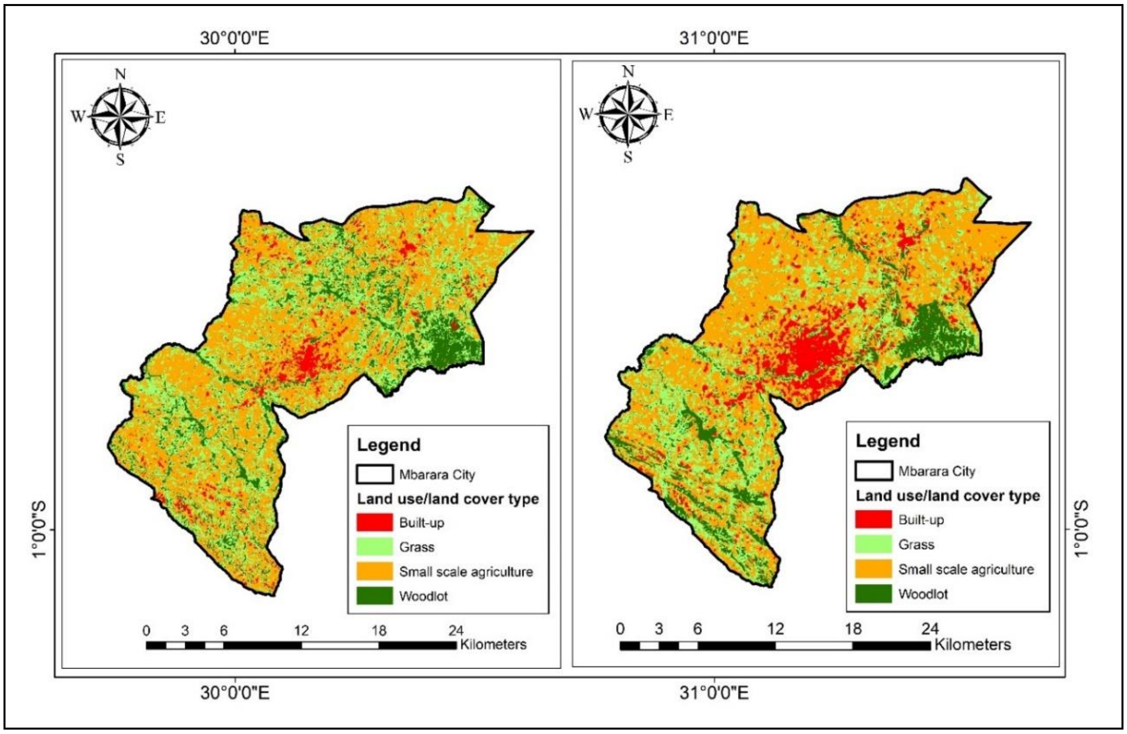
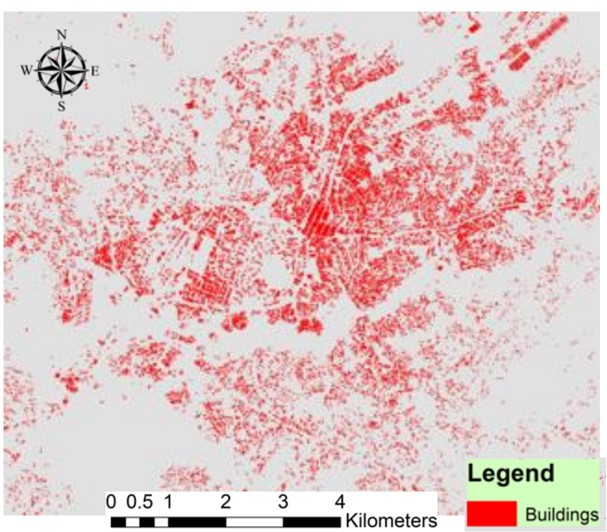
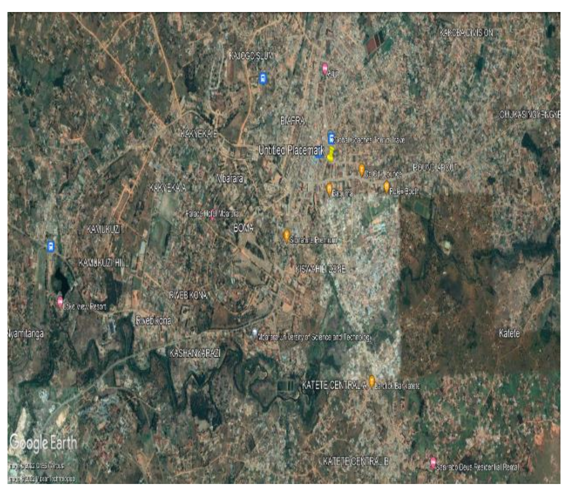


Figure 4: General overview of Mbarara City land fragmentation, slum development, and impact of built-up area on grazing area

a) is extracted built-up area from the land use map



b) is a Google Earth image over slums of Mbarara City



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c) is a competition of built-up areas and land fragmentation on grazing land

d) is construction material deposited on the grazing land

The results of the analysis showed that the land use/land cover types in the Mbarara district included built-up (1,879.43 Ha), grassland (13,538.62 Ha), small-scale agriculture (22,644.51 Ha), and woodlot (6,001.67) in 2010 while in 2022, built-up was (4,144.73 Ha), grassland (10,440.77 Ha), small-scale agriculture (23,797.14.51 Ha), and woodlot (5,681.59), (*Table 2*). There was an increase in a built-up area (4.27% from 2010 to 9.41% in 2022). Grassland reduced from (30.72% in 2010) to (23.69% in 2022), small-scale agriculture increased from (51.39% in 2010) to (54.01% in 2022), and woodlot reduced from (13.65% in 2010) to (12.89% in 2022). However, the decrease in land use/land cover was statistically significant between 2010 and 2022 ($p = 0.03$).

Table 2: Land use/land cover type

Land use/land cover type	**2010**		**2022**	
	Ha	**%**	**Ha**	**%**
Built-up	1,879.43	4.27	4,144.73	9.41
Grassland	13,538.62	30.72	10,440.77	23.69
Small-scale agriculture	22,644.51	51.39	23,797.14	54.01
Woodlot	6,001.67	13.62	5,681.59	12.89
Grand Total	44,064.24		44064.24	

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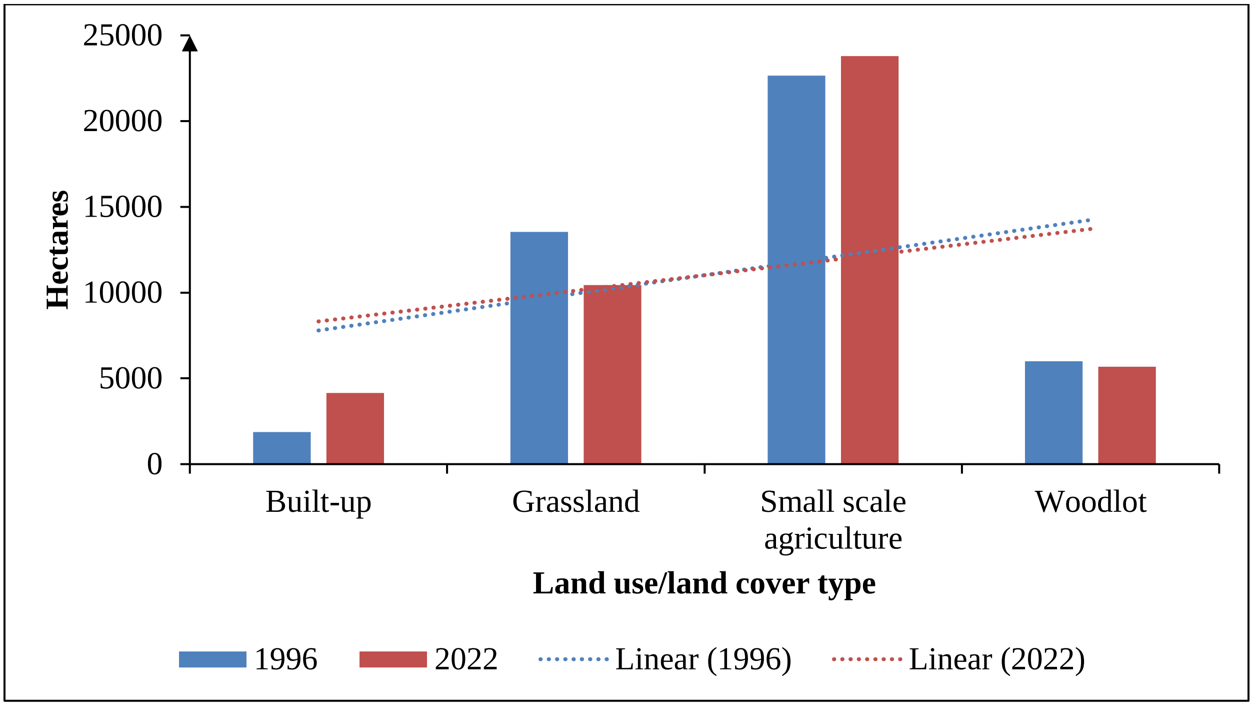
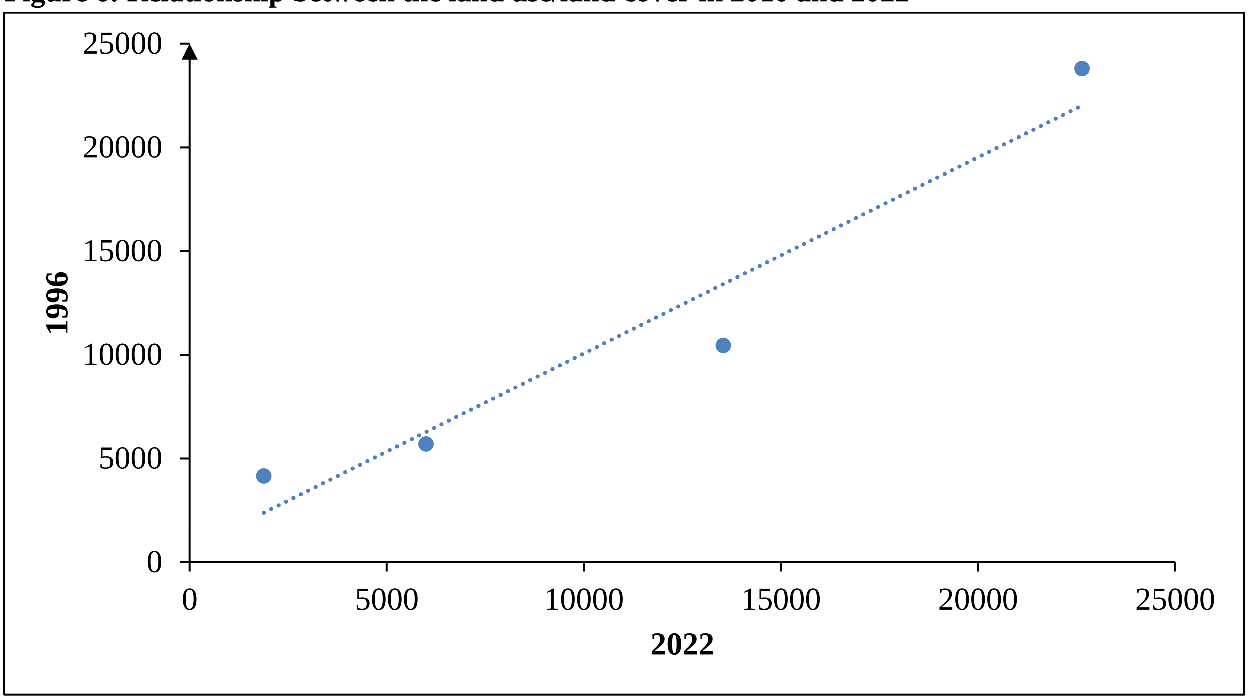
Figure 5: Land use/land cover distribution in Mbarara City



The results from the analysis revealed in 2010 and 2022 small-scale agriculture were the dominant land in Mbarara City followed by grassland, and woodlot and the least were built-up areas (*Figure 5*). However, an exponential increment in the built-up area was recorded in 2022 (p = 0.03).

Figure 6: Relationship between the land use/land cover in 2010 and 2022



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The results from the analysis showed that the decline in land use/land cover in both 2010 and 2022 evidenced a strong positive correlation (r = 0.97, *Figure 4*). However, the relationship between 1996 and 2022 was statistically significant (p = 0.97).

DISCUSSION

Through evidence from remote sensing, land use/land cover dynamics were real from 2010 to 2022. This was observed from the spatial patterns of built-up areas, grassland, small-scale agriculture, and woodlot that showed significant changes. Grassland has reduced due to an increase in the size of built-up areas, and small-scale agriculture. A 4.87% and 2.62% increment in a built-up area and small-scale agriculture between 2010 and 2022 can evidence why the grassland area is reducing which is attracting land fragmentation and slum development in Mbarara City. The increase in built-up area and small-scale agriculture could be attributed to the high level of urbanization in the cities in Uganda as well as demand for food could well explain the reason behind the increase in small-scale agriculture (Mukwaya *et al.*, 2010; Mbabazi & Atukunda, 2020; OECD/UN ECA/AfDB, 2022). The other reason for the increase in small-scale agriculture within Mbarara City could be attributed to the increasing human population people (Uganda Bureau of Statistics, 2016; Nuwagaba, 2022).

The increase in the number of unplanned settlements most especially in Katete and Kakoba has led to the development of slums in Mbarara City. Field observations made in December 2022 also evidenced that many slums exist in Mbarara City and they are increasing due to accelerated urbanization. More so, evidence from the previous study also noted that unplanned cities can lead to the development of slums which is in agreement with our study findings (Nuwagaba, 2022).

However, in the past decade, slum development was noted even before Mbarara Municipality was uplifted to a city status because of its growing population. Media stories have also evidenced the development of 12 slums in Mbarara City including Akachwampare, Kihangire, Tankhill, Kirehe, Kiswahili, Kijungu, Kisenyi, Kahanyarazi, Biafura-Kajogo, Butabika and Kiyanja with the sizes of houses ranging from 8ft by 8 ft, and 10ft by 12ft (New-Vision, 2021; Monitor, 2022). Such findings corroborate my study finding captured by the land use/land cover dynamics. This can be seen from the spatial-temporal patterns observed from the remote sensing evidence of the land use/land cover dynamics within Mbarara City.

Our study revealed that woodlot size was reduced by 0.73% between 2010 and 2022. The decline in the woodlot coverage could be attributed to the demand for more fuelwood needed for providing energy as well as the decrease in woodlot coverage could be due to more demand for construction poles in Mbarara City. According to the Global-Forest-Watch, (2021), between 2010 and 2021 Mbarara district where Mbarara City is located lost 1.74 kha of forest which is in agreement with our study findings. Forest decline was evidenced to decline in Uganda between 1990 to 2015 (MWE, 2016), such a decline could well explain the decline in tree coverage in Mbarara City between 2010 to 2022.

The other reason could be attributed to the charcoal burning activities because of the presence of Acacia species and eucalyptus species that provide good charcoal (Bamwesigye *et al.*, 2020; Kansiime *et al.*, 2022). Furthermore, there is more demand for electricity poles by the factories that treat electricity poles in Mbarara City because the poles are used in rural electrification projects.

CONCLUSION

Our paper analysed the impact of land use/land cover dynamics on grassland areas. The land use/land cover types that existed in Mbarara City included built-up areas, grassland, small-scale agriculture, and woodlot. However, the land use

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types that had much influence on the reduction of grassland areas included expansion of the built-up area and small-scale agriculture. Unplanned built-up areas facilitated land fragmentation and the development of slums. The increase and the decrease in land use/land cover types were significantly different between 2010 to 2022. Our discussions focused majorly on the impact of the increase of built-up, and small-scale agriculture on grassland areas which in the long run led to land fragmentation and slum development. Mbarara City should focus majorly on encouraging people to avoid subdividing land into small parcels to reduce land fragmentation and slum development.

Recommendations

The government of Uganda should put up strict laws and regulations governing the sub-division of land. In addition, Mbarara City Authority should encourage people to make plans before constructing houses in a particular area to reduce the level of land degradation and slum development. The government of Uganda should sensitize people in Mbarara city about the disadvantages of subdividing land into smaller pieces and discourage the development of more slums. The Mbarara City Authority should educate people more about the advantages of rangeland areas as a way to promote climate change and the green economy.

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