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Original Article

The Role of Remote Sensing in Forest Cover Changes in Butambala District, Central Uganda

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Land use/cover Changes, GIS, Remote Sensing, Forest change.

ABSTRACT

Natural forests in Uganda have experienced changes which must be quantified to inform future forest resource management and avoid the danger of reduced ecosystem service benefits. The primary purpose of this study was to assess forest changes in Butambala District by employing remote sensing techniques and GIS tehniques. The original contribution is the capacity to detect Central Forest Reserve cover decline using remote sensing in the study area for a 27-year period (1995-2020). Landsat 5 and Sentinel 2 images were processed using a supervised image classification approach to identify and quantify land use/cover changes. The study results indicated that the district has undergone land cover/use changes over the last 27 years. The prevailing changes in the district from 1995 to 2022 were expansions of built-up areas from (0.54% to 4.22%), agriculture from (42.38% to 79%), and decreases in grassland from (29.9% to 0%), natural forest cover from (14.07% to 5.9%), wetland from (8.24% to 7.9%), tree plantation from (4.87% to 3.3%). The changes threaten the environment and quality of life of people. Therefore, there is need to take critical and practical measures to regulate land use and landcover changes and conserve natural resources in Butambala District.

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INTRODUCTION

Land use and land cover changes have been evidenced as the main global cause of forest degradation, reducing forest biodiversity (Syampungani et al., 2014; Newbold et al., 2015). In addition, forests are declining at a rate of 10 million hectares per year in tropical African areas (Pendrill et al., 2019). In some African countries such as Madagascar, forest deforestation is induced by population escalation (Adesina & Zinnah, 2009; Clark, 2012). In East Africa, forest deforestation is caused by population growth and poverty (Lung & Schaab, 2010; Afrane et al., 2012; Guzha et al., 2018).

In Uganda, the reduction of forest cover is majorly attributed to the increased human activities such as agriculture, medicinal plant harvesting with poor methods, and timber extraction among others (Twongyirwe et al., 2011; Nuwagira et al., 2022). In addition, forest biodiversity loss has been noted to be influenced by forest clearance in Uganda (Bala et al., 2007; Twongyirwe et al., 2015a; Nakileza et al., 2017; Josephat, 2018). According to Bernard et al. (2011), environmental impacts due to land use and land cover changes in Uganda remain a big debate. This is because changes in land use can transform the environment from a bad to a worse state in terms of changes to the climate, resulting in global warming (Dirmeyer et al., 2010; Pielke Sr et al., 2011; Brouwer et al., 2012; Deng et al., 2013).

Besides, a population increment rate of 3.6 percent per year can also trigger forest deforestation in the long run, affecting the forest's biodiversity (UBOS, 2016; Josephat, 2018). More so, the population of Central Uganda is 9.52 million people (UBOS, 2016), and this is where the study area is located. With spontaneous forests degradation in Uganda, the remaining forest cover provide great benefits such as carbon sequestration, climate regulation, provision of medicinal plants, and provision of habitats for different animals including mammals and reptiles (Obua et al., 2010; Banana et al., 2012; Sassen et al., 2013; Sassen et al., 2015; Nuwagira et al., 2022).

Central Uganda has Several Central Forest Reserves (CFRs) including Mabira, Mpanga, Lwamunda, Buvuma, Navugulu, Katabalalu, Nawandigi, Gangu, and Wantagalala (Obua et al., 2010). However, the Central Forest Reserves which exist in Butambala District include Navugulu, Katabalalu, Nanfuka, Nawandigi, Gangu, and Wantagalala which are currently undergoing degradation. The degradation of forests in Uganda was significantly noted in the early 2000s (Banana & Gombya-Ssembajjwe, 2000; Kayanja & Byarugaba, 2001). In addition, in 2018 forest degradation was noted as an indicator of forest loss mostly in Central Uganda where Butambala District is located (Josephat, 2018). A study by Sassen et al. (2013), evidenced that forest degradation in Uganda is mainly due to encroachment of the communities near the Central Forest Reserves.

The degradation of Central Forest Reserves is at a huge rate which in a long run implies forest biodiversity and Ecosystem Services Provisioning (Bamwesigye, et al., 2020; Doli et al., 2020). Several land use and land cover studies have been conducted in greater Mpigi district, however most of these studies have focused on the general land use and land cover changes (Ssentongo et al., 2018). However, this study seeks to determine the impact of land use changes between 1995 and 2022 in Butambala District with the use of Remote Sensing with emphasis on Central Forest Reserve cover change. This is because Remote Sensing is a vital tool in collection of information that is very significant in natural resource management (Mengistu Bahir et al., 2007; Usha & Singh, 2013; Andrew et al., 2014; Rocchini et al., 2016; Khanal et al., 2017) including assessment, mapping, and monitoting of forests (Torres et al., 2021).

MATERIALS AND METHODS

Study Area

The study area was Butambala District in central Uganda. The District lies between latitude 0° 9'25.79"N and longitude 32° 3'31.04"E. The District neighbours Mityana to the North, Gomba to the West, Wakiso to the East, Mpigi and

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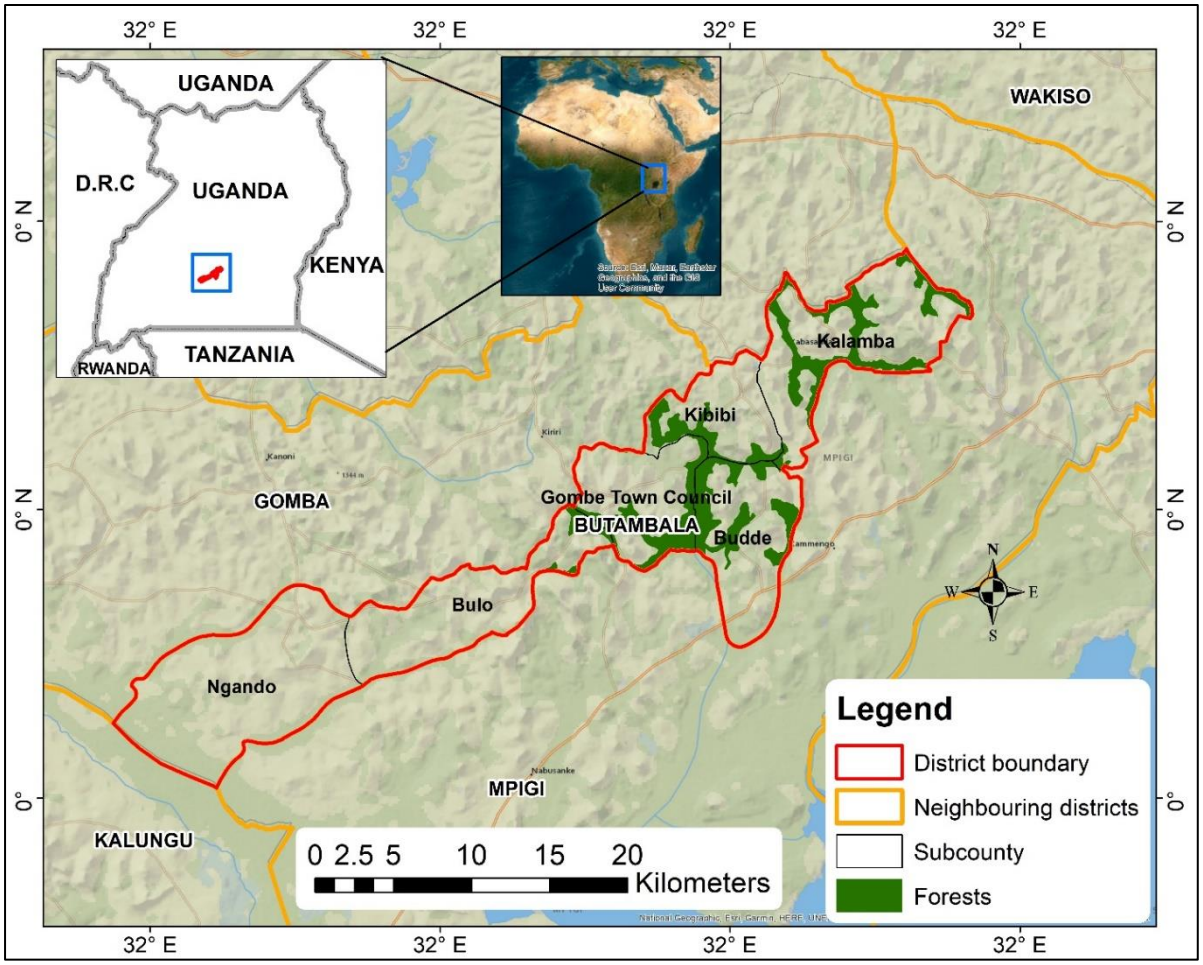
Kalungu districts to the South (*Figure 1*). In addition, precipitation ranges from 750 mm to 2000 mm, with the minimum temperatures ranging between 15-17.5 ^{0}C and maximum 17.5 - 20 ^{0}C (Ssentongo et al., 2018).

Figure 1: Location of the study area



Data Collection and Data Processing for Land Use and Land Cover Mapping

The data used in this study was obtained from the United Stated Geological Survey (USGS) website at (https://earthexplorer.usgs.gov/). The 1995 satellite image was obtained from Landsat 5 while 2022 satellite image was obtained from Sentinel 2. In addition, only cloud free images were employed in land use/land cover mapping to avoid errors during image classification (Liu et al., 2017; Pan, 2020; Ebel et al., 2022). The details of the satellite images are in (*Table 1*).

Table 1: Satellite image information

Date	Satellite	Path/Row	% Cloud cover	Resolution (m)
5/02/1995	Landsat 5	172,171/060	<10	30
7/30/2022	Sentinel 2	172,171/060	<10	20

Land use and land cover mapping involved both pre-processing, and classification procedures. Pre-processing involved band stacking and band composition to form an RGB, improving on the image brightness, and transparency (Ssentongo et al., 2018). In addition, classification which involved supervised image classification was employed in land use and land cover mapping because it involves selecting sample pixels that represent particular classes that direct the image processing software to use them as reference sites (Domadia & Zaveri, 2011). This step later helped

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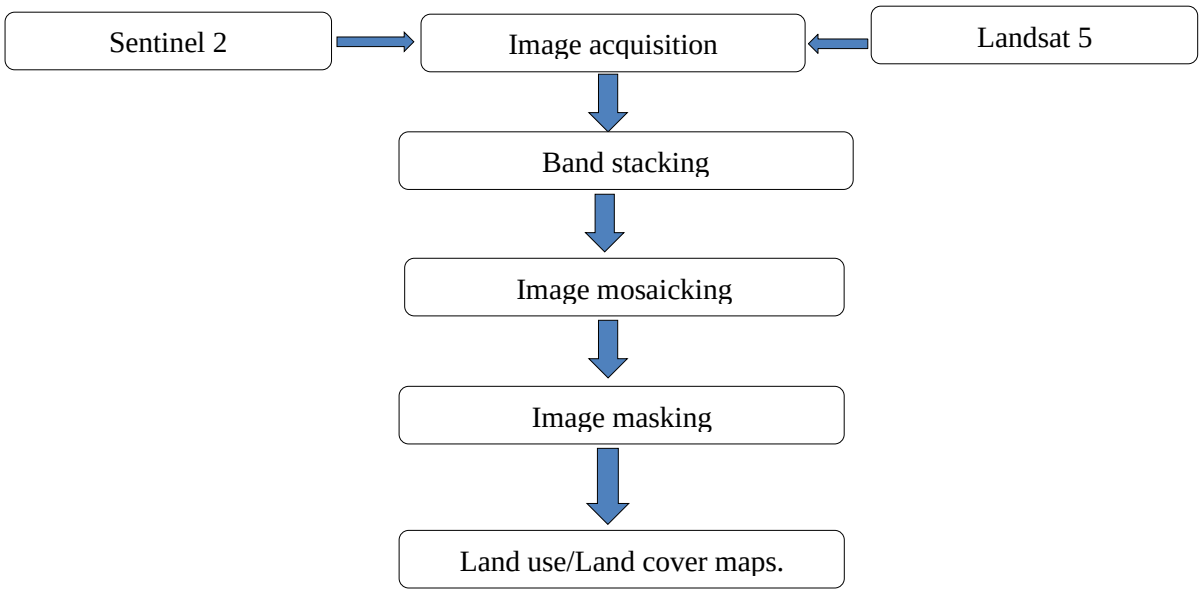
in differentiating reflactance from the earth's surface to develop the land use and land cover maps for the study area following procedures by Twongyirwe et al. (2015b).

Figure 2: Flow chart of methodology used in classifying land use and land cover changes.



Data Analysis

The analysis of land use and land cover mapping was performed in ArcGIS version 10.8. In addition, supervised image classification was employed to identify the land use and land cover changes within the study area whereas Microsoft Excel version 2019 was used in data presentation particularly in developing a graph showing area coverage of different land uses/land cover types.

RESULTS

Generally, between 1995 and 2022, there was a 58.1% decline in the change in natural forest cover. Furthermore, spatially, tree plantations between 1995 and 2022 also declined (32.2%) in Butambala District, which is shown in (*Figure 3*). The results further revealed that built-up area had 219.09 ha (0.54%) followed by grass 12,119.16 ha (29.90%), natural forest 5,704.497 ha (14.07%), agriculture 17,181.11 ha (42.38%), tree plantation 1,974.42 ha (4.87%), and wetland 3,339.72ha (8.24%) in 1995 (*Figure 3*) while in 2022 analysis of the results revealed that built-up area had 1,711.72 ha (4.22%) followed by grass 0 ha (0%), natural forest 2,409.80 ha (5.9%), agriculture 3,1853.22ha (79%), tree plantation 1,328.23 ha (3.3%), and wetland 3,235.03 ha (7.9%). More so, natural forest and tree plantation losses dominated in areas with many built-up areas as observed from the land use map 2022 (*Figure 4*). Apparently, natural forest and tree plantation decline was seen to be caused by the increase in agriculture in the area. The decline in the patches of grass was also replaced by agriculture in Butambala District.

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Figure 3: Butambala District land use/land cover maps

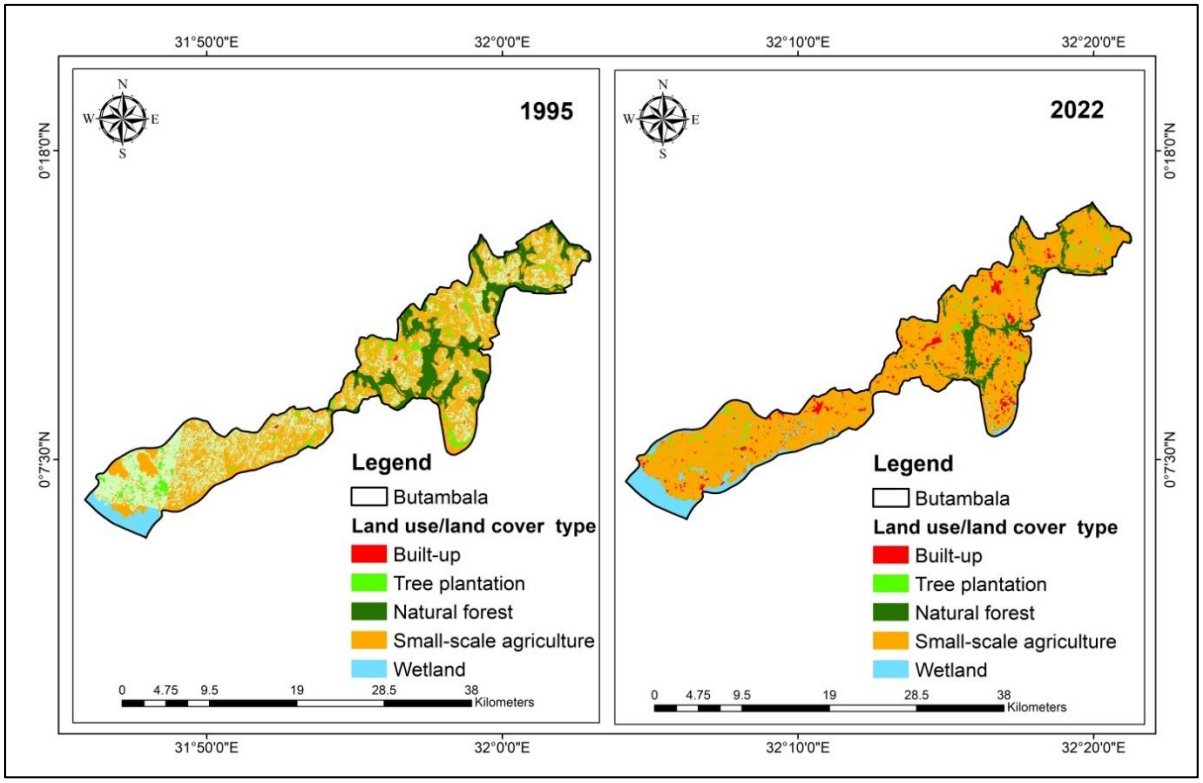
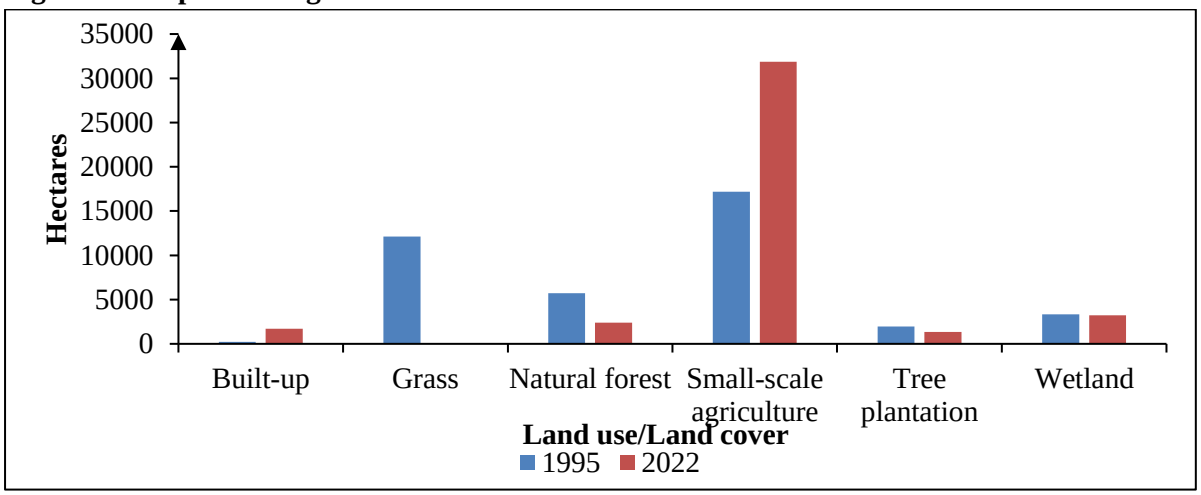


Figure 4: Graph showing Butambala land use/land cover



DISCUSSION

The classification yielded accurate land cover/use maps for the two images. Results of the land cover and land cover analysis from 1995 to 2022 indicated that Butambala District had been subjected to significant LULC changes. This shows that two land use/cover classes of agriculture, and built-up gained more area from grassland, natural forest, tree plantation, and wetland in the 27year period considered in the study. There was a decline in grassland, natural forest, tree plantation, and wetland land covers with an overall rate of decline most pronounced in grassland, and natural forest that reduced by 29.9%, and 8.1%, respectively.

On the other hand, the overall rate of increase in agriculture between 1995 and 2022 was 36.2%, which pattern was equally observed among built-up areas. A study conducted in Central Uganda evidenced that agriculture had increased in the last 3 decades (Mwanjalolo et al., 2018), which is in line with the findings of this study.

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Comparatively, agriculture was rising faster than built-up areas accounting for 79% of the total land area compared to 4.2% for built-up areas in 2022. These vacillations led to visible changes in the spatial patterns of the land use/cover which could be attributed to crop growing through shifting cultivation (Li et al., 2016).

Based on the observations from this study, it is apparent that subsistence agriculture is currently dominant in Butambala District. The positive change for the two classes (agriculture and built-up classes) could be attributable to shifts and trade-offs between these classes; shifts and trade-offs between land use classes have been reported in the same area by Ssentongo et al., (2018). The socio-economic factors, such as escalating poverty and population growth, are another explanation for these shifts, which is why seasonal crops are needed to generate quick cash. More work is put into clearing forest area to create rich soil as the yield declines.

Field visits suggest that even more areas of natural forest land are continuously being encroached and turned into agricultural land, and plantation. Another reason for the increase in agriculture in the study area could be the increasing human population, which raises demand for agricultural land as evidenced in a study conducted by Josephat, (2018). The annual population change in Butambala District was recorded at 1.2% between 2015 and 2020, according to UBOS (2020). The rise in built-up area over the research period can also be attributed to slightly higher levels of urbanization in various areas of the District, particularly in town councils. The results further reveal that tree plantations declined between years of 1995 and 2022. This decrease in plantation coverage can be ascribed to a high demand for fuelwood in the area, which is required to produce energy for households, as they rely mostly on biomass. This correlates with studies conducted in the Central region by Egeru, (2014); Gebru & Elofsson, (2023); Jagger & Kittner, (2017); Mainimo et al., (2022).

This study further showed that there was a decline of 42.24% in natural forest between 1995 and 2022. The total natural forest land lost between this period amounts to 3,294.693 hectares. Forest cover decrease due to land use changes has been seen in both central forest reserves and privately held forests in Uganda. This collaborates with a study by Josephat (2018); Ssentongo et al. (2018), who reported that forests had declined by 53.1% during the period of 1986 and 2005 within the administrative boundaries of five sub-counties in Mpigi and Butambala districts. Most of the encroached-on land in forest reserves in the study area is used for *Eucalyptus* growing and agriculture cultivating mostly seasonal crops that allows farmers to get crop income within a short time.

CONCLUSION

While grassland, natural forest, tree plantations, and wetland land covers experienced significant decreases, agriculture and built-up areas expanded substantially. The study provides a reliable opportunity for natural resource managers and policymakers to respond effectively to the dynamic and complex changes that threaten the integrity of Butambala District. Long-term participatory land use planning is encouraged, and the general public, private landowners and other development players should all be included. Furthermore, all stakeholders must work together to promote agroecology and restore degraded natural forests. A detailed examination of the observed land use/cover change's implications on projected environmental services and local human well-being is required.

Recommendations

To prevent further land use/cover conversions, Butambala District Local Government should enforce adherence to existing policies, laws, and regulations governing natural resources in the area. Butambala District Leadership should create guidelines and ordinances to manage remaining forests in a sustainable manner while also facilitating restoration of degraded areas. Moreover, Butambala District Local Government ought to promote the sustainable utilization of natural resources to enhance livelihoods and bolster resilience against climate change-induced

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disasters through education and awareness campaigns such as agroforestry adoption, enrichment planting, reforestation and afforestation. These awareness campaigns should diminish reliance on natural forests for fuelwood.

Additionally, communities should be encouraged to participate in government initiatives like the Parish Development Model (PDM), Special Enterprise Grant for Older Persons (SEGOP), Uganda Women Entrepreneurship Programme (UWEP), and Youth Livelihood Programme (YLP) to further enhance their livelihoods. Carbon trading schemes can be used to prevent further natural forest degradation; this can be accomplished by determining the carbon storage potentials of all forests in the District and capitalizing on the established capacities for inclusion in results-based carbon trading schemes, while also ensuring that the benefits of carbon trading reach the local community as incentives for not invading the forests in search of fuel wood and livelihood stability. Butambala District Local Government's Natural Resources Department should receive additional support through training and capacity-building initiatives from Ministry of Water and Environment and other development partners. This support will enable them to grasp the concepts of carbon finance and identify opportunities for initiating carbon finance projects that will bring benefits to communities. With arise in built-up areas in the District, Butambala Local Government and the Ministry of Lands, Housing and Urban Development should encourage individuals to construct in accordance with plans in order to avoid land degradation and slum growth.

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