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Original Article

The Trends and Magnitude of Tree Plantation Growing in Rural Communities of Kigezi Sub-region, South Western Uganda

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ABSTRACT

The study documents the trends and magnitude of tree plantation growth in the Kigezi Sub-region of South Western Uganda. In most developing countries, national governments have been promoting and supporting rural communities with tree-planting programs in the region. A trend analysis was used to determine the escalating tree plantation growth in the sub-region. Landsat (TM/ETM+) satellite images were used to capture the trends, and a survey was also used to obtain information on the distribution patterns of established tree plantations. A randomly selected sample of 389 tree plantation growers was surveyed. The research approaches adopted were to supplement and strengthen the findings and also to provide an opportunity for the researcher to understand in-depth how tree plantations grow in the rural livelihood economy. Recommendations from this study emphasise the strengthening of the existing policy reforms. Also, interventions to harness sustainable forestry management should be used to provide integrated benefits to all, ranging from safeguarding local livelihoods to protecting the biodiversity and ecosystems provided by forests and reducing rural poverty in the Kigezi sub-region.

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INTRODUCTION

According to the 2020 Global Forest Reserve, the global rate of net loss of forests has substantially decreased between 1990 and 2020 due to a reduction in deforestation rates in some countries (Miyamoto, 2020; Caravaggio, 2020; Tubiello et al., 2021). The recent increasing trends of areas under forests have been attributed to the increasing demand for forest products (Sloan & Sayer, 2015;). The highly changing market for forest products has been the key driver for these trends within the tropics (Cubbage et al., 2014).

Also, the perceptions about forests being protective and their provision of a wide range of services have facilitated their increased planting within the tropical region (Pearce et al., 2003). These have led to the establishment of the small householder and community-level tree planting projects contributing to income generation also attributed to the natural regeneration, restoration and reforestation activities (Stewart, 2012). These have been strengthened by the fact that tropical forest clearing comprises at least 12% of carbon emissions (Van Der Werf et al., 2009).

Since the 1950s, areas under planted forests have been increasing, a trend that is expected to continue for the next decades (Keenan *et al*., 2015). It is estimated that tree planting increased rapidly between 1990 and 2010 worldwide, including the tropics. According to the analysis of data from 2015, the Forests Resources Assessment of the U.N. Food and Agriculture Organization proved the total forest area, however, increased from 167.5 to 277.9 million hectares or 4.06% to 6.95% of the total forest area, with these trends dominating in the tropics (Payn et al., 2015).

Similarly, in the subtropics, there has been an increasing forest cover and is associated with planted forests (Hansen et al., 2013). Recent estimates placed the global extent of planted forests at 278 million ha in 2015 (Odebiri et al., 2020), with tree plantations of fast-growing tree species occupying 54 million ha in 2012 and predicted to double in extent by 2050 (Bahar et al., 2020).

Initially, forests within the tropics declined due to increasing population density leading to encroachment on agricultural land for food crop production (Gibbs et al., 2010). Therefore, the highly changing behaviour is for the recent market of forest products, the key driver for these trends within the tropics (Cubbage et al., 2014). Generally, in developing countries, national governments have been promoting and supporting the development of tree plantations and woodlots for climate, conservation as well

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as livelihood purposes (Bremer & Farley, 2010). The support from the government has been in the form of free tree seedlings, provision of extension services and taxation-free forestry inputs.

In Uganda, the government and its development partners have promoted tree plantation as well as on-farm plantations with the key objective of alleviating high rural poverty through income and employment and addressing the high deforestation rate (Jacovelli, 2009). Through projects such as Saw-log Production Grant Scheme (SPGS), the Farm Income Enhancement and Forest Conservation Project (FIEFOC) and National Agricultural Advisory Services (NAADS), several tree plantations and woodlots in tens of thousands of hectares were developed across the country (Koboggoza, 2011; Kiyingi *et al.,* 2015).

Monoculture of tree species such as pine and eucalyptus has become a more attractive venture (Balimunsi et al., 2012). These plantations play a significant role in the national development and local livelihood, and through their contribution to environmental protection, timber production, and provision of energy, industrial use as well as a major source of quick income for individuals and households. Although tree plantations come with benefits, the environmental and social impacts of these types of plantations have caused them to become controversial (Balimunsi et al., 2012). This Agroforestry intervention in the form of tree plantations was adopted in Uganda (Turyasingura et al., 2022; Turyasingura & Chavula, 2022a) but specifically found in South Western Uganda. These tree plantations are established at different scales to meet the primary forestry objective for the Conservation Farm Income Enhancement under Forestry Projects; hence, increased diversity resilience is in line with (Turyasingura et al., 2022), who said that diversity at the landscape level is paramount to promoting resilient livelihoods as a means of improving the health and functioning of socio-ecological systems, as well as a mechanism for achieving food security.

General Objective of the Study

To assess the trends and magnitude of tree plantations growing in the Kigezi Sub-region

Objectives of the study

- To assess the trends of tree plantations growing in the Kigezi Sub-region.
- To examine the magnitude of tree plantations growing in the Kigezi Sub-region.

THEORETICAL PERSPECTIVE

This study has been guided by two theories: Planned behaviour and Boserup's theory. Planned behaviour theory states that people engage in any activity after weighing the benefits and negative consequences (Ajzen, 2011, 2012). Therefore, the decision to plant trees will be largely determined by the degree to which one understands and addresses the factors which encourage or discourage farmers from planting trees (Sok et al., 2021). It is about rationalising the most lucrative land use for the available land resource.

More importantly, in this study, Boserup's theory on induced intensification was used in understanding how pine and eucalyptus tree planting affects livelihood activities or responses of people in the Sub-region. It has

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been argued that, with respect to land pressures arising from pine and eucalyptus tree planting, the agricultural intensity may increase or decrease with land pressure. Thus, induced intensification explains changes in agricultural intensity and by implication, changes in the technology and management of cultivation (Hirwa et al., 2022). It employs an understanding that the behaviour of smallholder farmers changes to any induced pressure on land (Zheng et al., 2022). For example, demands due to land pressure or population growth require techno-managerial strategies of production (Germond-Duret, 2022).

REVIEWED LITERATURE

Globally, it is estimated that over 200 million people depend entirely on forests for their livelihoods (FAO, 2020). Depending on the degree of reliance on forests for livelihood, it is estimated that over 350 million people rely on forests for subsistence and income (Rasmussen et al., 2017). In developing countries, forests play a key role in leveraging the livelihoods of households, especially in rural areas (Langat et al., 2016; Clements et al., 2014; Lubembe et al., 2022). In rural areas, about 20-25% of people's income is derived from environmental resources including forests, construction materials, medicine, food, and fuel wood are some of the materials derived from forests (Wunder et al., 2014; Krishnakumar et al., 2012). In periods of crisis for instance, during food shortages, forests act as safety nets, especially for indigenous communities and those living near the forest (Food and Agriculture Organisation of the United Nations, 2015).

In countries like Uganda, the human population is noted with a high growth rate of 3.3% (Uganda Bureau of Statistics [UBOS], 2014). Such a rapidly growing population threatens environmental resources (Laurance et al., 2014). The land pressures for settlement and cultivation limit the availability of land for agriculture (Laurance et al., 2014). Such agricultural practices are unsustainable for tree growth.

Additionally, the removal of trees for wood fuel is prevalent as most households rely on firewood or charcoal as their main source of energy (Gelabert et al., 2011). Resource use grows alongside people's aspirations to improve their lives, and one of the results related to this is the high deforestation of both planted and natural forests (Lindenberg, 2002). A steady growth towards becoming a middle-income country depends on healthy management of the environment and natural resources, which includes tree planting and sustainable management (Koeser *et al.,* 2014).

In many countries, forest management continues to be among the least funded sectors by donors and governments (Davies et al., 2017). There has been a decline in funding for forestry explained by changes in donors' sectoral priorities from forest management towards the social sectors (Easterly & Williamson, 2011). While governments like that of the Republic of Uganda have demonstrated a commitment to improving forest management through a multiplicity of strategies contained in the National Development Plan (NDP) and agricultural sector plans, the renewed call for a specific focus on farmers of tree production comes in the wake of the appalling economic growth rates (UBOS, 2014), relatively high poverty rates and increasing food insecurity

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(Turyasingura et al., 2022). At the district and national levels in countries like Uganda, private tree planting is often overlooked (Kakuru et al., 2014).

Only limited initiatives exist to support private tree planting, or if they are, they rarely benefit the tree owners (Turyahabwe et al., 2007). Some of the serious challenges facing tree planting on private land include continuous human population pressure on lands and forestry resources (Ssenku, 2022). High population pressures on limited lands and forest resources have led to the breakdown of traditional tree-based systems and practices that allow the regeneration of vegetation cover (Ssenku, 2022).

MATERIALS AND METHODS

Study Area

This study was carried out in the Kigezi Sub-region of South Western Uganda in accordance with the findings of Turyasingura et al. (2022a). The study covered five districts of Kanungu and Greater Kabale (Rukiga, Rubanda, and Kabale, *Figure 1*). These districts were purposely chosen due to being major beneficiaries of plantation forests in Uganda (Kaboggoza, 2011; SPGS, 2010). The study was conducted in the Kigezi Sub-region, in the districts of Greater Kabale (1.2420S, 299856E) and Kanungu (819I5S, 297426E), with a total land area of 1,827 sq km, neighbouring Kisoro District, the Democratic Republic of Congo and Rwanda (Benson & Ayiga, 2022). The area bordering the region has natural reserves of forests and wildlife shared by the community. For example, the Mughinga and Bwindi Impenetrable National Parks reserves. The Kigezi Sub-region is a rolling, mountainous region in the foothills of the Virunga Mountains. The altitude varies between 1800 and 2800 m above sea level (Turyasingura et al., 2022). Hill slopes are very steep and can exceed 50°. According to Turyasingura and Chavula (2022b); Turyasingura et al. (2022) who said that soils in Kigezi are deep and fertile but have become degraded due to poor and unsustainable farming practices. The region enjoys a moderate tropical climate with an average annual rainfall of 1000–1500 mm. The rainfall pattern is bimodal, with a long rainy season from March to June and a short rainy season from October to December. The mean maximum and mean minimum temperatures are 23 and 10 degrees Celsius, respectively (Saturday et al., 2021).

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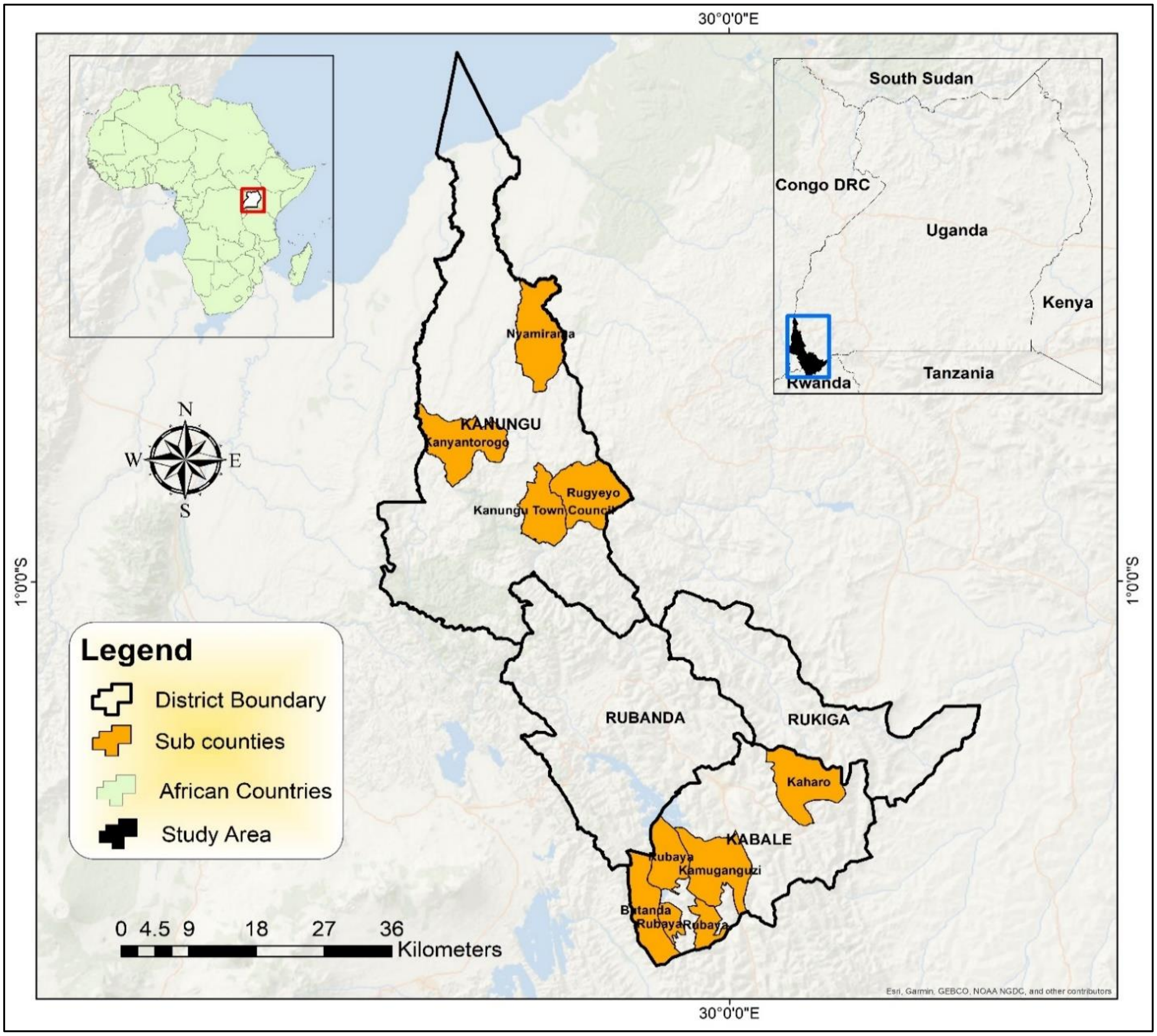
Figure 1: A Map showing the Greater Kabale and Kanungu Districts of the Kigezi Subregion



In addition, these districts have small land parcels (average <2 acres) per household, known as smallholder cropping systems with high population density and very competitive land uses including for instance, agriculture, forestry, and settlements (including urbanising and rural areas). In Kanungu, the study was conducted in Kanyantorogo, Rugyeyo, Nyamirama and Kanungu Town council sub-counties, whereas in Kabale, the study was conducted in Kaharo, Rubaya, Butanda and Kamuganguzi sub-counties. The land cover covering Kigezi Sub-region is dominated by subsistence farmlands followed by woodlands (Lwanyaga, 2022). It has grasslands and shrubland especially found in national parks. This region happens to have the highest concentration of high tropical forests, although most of them now are restricted to protected areas. It supports rich and varied habitat types including grassland savannahs, wooded grassland, bushlands, woodlands, thicket, forests and wetlands that provide varied ecosystems that in turn support a high diversity

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of both flora and fauna. The major ethnic tribes include Bakiga, Bahororo, Banyarwanda and others. The target population of the Kabale and Kanumgu districts is 503.775 population density (UBOS, 2014).

Research Design

A descriptive cross-sectional research design was employed in this study. Both qualitative and quantitative approaches were used to collect data on tree plantation trends and land cover change in the Kigezi Sub-region.

Data Collection

Simple random sampling and purposive sampling methods were used to select the participants from the selected parts of the Kigezi Sub-region for the quantitative and qualitative parts of the study, respectively. Simple random sampling was used to select a representative sample of respondents in the selected districts of the Kigezi Sub-region. The participants in the quantitative survey targeted individuals who were pine and eucalyptus farmers. Whereas the farmers for focus group discussions were both tree growers and non-pine or eucalyptus farmers in the area. The purpose of having selected both farmers of pine and eucalyptus and non-pine or eucalyptus farmers was to detect the land use practices and livelihood effects associated with exotic forest plantations. Since the actual target population of pine and eucalyptus farmers in both districts is not known, the sample size was determined based on the following formula:

$$n= z^2. [p*q]/d2),$$

Where n is the sample size, P is the estimated proportion of the study population assumed at 50%, q = 1-P (50%), and d is the margin of error (5%). z is the Z-score = 1.96 at a 95% confidence level. To take care of non-response assumed at 5%, the formula that was used for sample size determination is defined as:

$$n = 1.96^2 * 0.5*(1-0.5)/0.05^2 * (1/1-5\%) = (384.16) *(1/0.95) = 404 \text{ respondents.}$$

The selection of farmers was made randomly based on the list of farmers list generated with the help of village leaders and forest group leaders in the selected villages in the Kabale and Kanungu districts. However, during the data collection, 389 respondents dully answered the questionnaire representing a 96% response rate. In addition, remote sensing and GIS, Survey questionnaires, Focus Group Discussions, Key Informant Interviews and Field observations were employed in order to achieve the objectives.

Satellite Image Acquisition, Processing and Plantation Change Analysis

This study utilised three ortho-rectified and cloud-free Landsat TM/ETM images (30 m) of 2000, 2005, 2010, 2015 and 2020 of average 5-year intervals. Preferred Landsat images were gathered from the United States Geological Survey. Satellite images corresponding to 1.2420° S, 29.9856° E containing both Greater Kabale and Kanungu districts were obtained from the USGS website, glovis.usgs.gov, a website that offers free satellite imagery. The study took 2000 as a base year; Landsat images at a 30-meter resolution were used due to the availability of historical images compared to the newer sensors such as Planet and Sentinel. Landsat imagery is also free.

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Table 1: Characteristics of Landsat images

Sensor	Year	Projection	Cloud cover percentage	Image date acquired
LANDSAT 5	2000	UTM WGS 1984	Less than 20	23/4/2000
LANDSAT 5	2005	UTM WGS 1984	Less than 20	15/9/2005
LANDSAT 5	2010	UTM WGS 1984	Less than 20	12/5/2010
LANDSAT 7	2015	UTM WGS 1984	Less than 20	26/7/2015
LANDSAT 8	2020	UTM WGS 1984	Less than 20	07/8/2020

Using Arc GIS 10.5, pre-processing of these images was done. The contrast and brightness of the Landsat 5,7.8 image were extracted from Greater Kabale and Kanungu districts to aid in the study; they also had their cloud-free positions in 2000, 2005, 2010, 2015 and 2020 images, respectively and were therefore considered the best for this study. False colour composites for all images were done to prepare them for classification.

Classification Method

Satellite images were also used to obtain detailed information on tree plantation coverage as explained. Landsat images were obtained due to their quality, various range of bands and spectral resolution of 30 m. The images used in this study were selected because of their availability, coverage, and low cloud coverage to facilitate information extraction, given the local climatic conditions within the area adopting the tree plantations. Images captured were from both Greater Kabale District and Kanungu District. Bands of downloaded images were merged in various combinations to form False Colour Composites, which were then used in classification (Dixit et al., 2021). Supervised classification was done by creating training samples from the satellite images for each year of interest, and the Maximum Likelihood classification tool in Arc GIS 10.5 was used to run the classification (Jackson & Adam, 2021). Supervised classification was done as it is easy to identify forest cover by its signature on a False Colour Composite mosaic (Garg et al., 2022).

Validity and Reliability of Visual Analysis and Google Historical

Ground truthing was done with the help of 100 random points generated for each image that was used in reference to Google Earth historical imagery. Confusion Error matrices were then used to calculate the overall accuracy of the classification for each image. The overall accuracy obtained from the User's and Producer's accuracy. The producer's accuracy is a measure of how well a certain area is classified. The consumer's or user's accuracy is a measurement of the reliability of the classification or probability (Bagwan & Sopan Gavali, 2021).

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Table 2: Sum of the diagonal elements

	User's accuracy	Producer's accuracy	Overall accuracy	Kappa coefficient
2015	88.3%	87.5%	87.9%	0.75
2020	90.7%	90.05%	90.3%	0.801

Data Analysis

Further analysis of the overall accuracy was done to cater for all elements of the error matrix including the errors of omission and errors of commission. The Kappa coefficient (Khat) is a measure of the agreement between two maps. If the Kappa coefficient equals 0, there is no agreement between the classified image and the reference image. If the Kappa coefficient equals 1, then the classified image and the ground truth image are totally identical. So, the higher the kappa coefficient, the more accurate the classification is (Pavel, 2016).

RESULTS

Trends of Tree Plantation Cover in the Kigezi Sub-region

The trend analysis of tree plantation covers between 2000 and 2020 in hectares is presented in *Figure 2* below, which shows that tree plantation cover has had an increasing trend from 2005 in line with Ajzen (2012). The tree plantation cover increased from slightly above 10,000 hectares in 2005 to more than 60,000 hectares in 2020. This represents more than 50% growth in plantation cover. The curvilinear trendline clearly shows that tree plantation cover has consistently risen over a 20-year period, and the R-squared value of 0.7222 is a good fit of the line to the data.

The findings also show the decline in the trend and extent of tree planting in the Kigezi sub-region in 2005 and 2015. This was attributed to declining tree plantation farming amidst the fast-growing population in the Kigezi sub-region. The lowest rate of tree planting was experienced in 2005 but later increased up to 2010. This was attributed to the SPGS project's supporting the tree farmers with finances and technical advice. Harvesting of some tree species was experienced in the year 2010-2015 and increased again from 2015 to 2020. There is evidence of an overall increase in the trend and extent of tree planting in the Kigezi Sub-region, according to the graph shown *in Figure 2* below.

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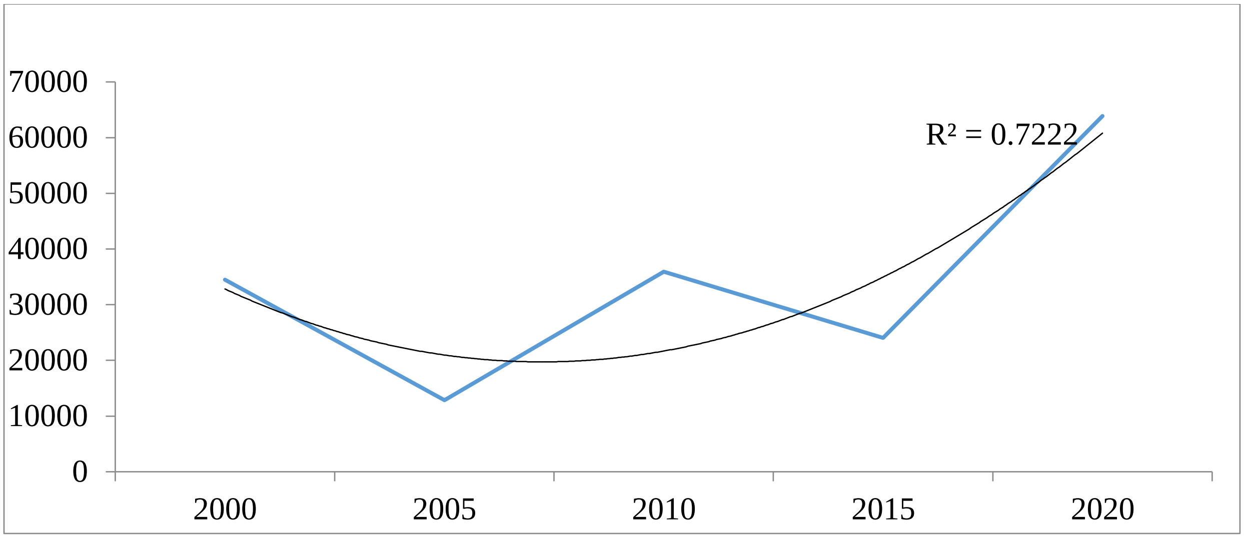
Figure 2: Trend of tree plantation cover between 2000-2020(ha)



Source: Primary data (Satellite images, 2020).

Coverage of Tree Plantations in the Kigezi Sub-region

Satellite images for the Kigezi Sub-region presented below show tree plantations growing. The image of the catchment land use and cover types are described based on field observations (*Table 3*, reflected in *Figure 2*). Field observations were also used as a basis for developing the image classification scheme through the categorisation of land use and cover classes. The scheme was customised because of the spectral reflectance of land use types and their distribution within the growing community. These are the description of land use cover classes used in capturing communities adopting tree planting in Kigezi Sub-regions of Kanungu and Greater Kabale Districts for image classification.

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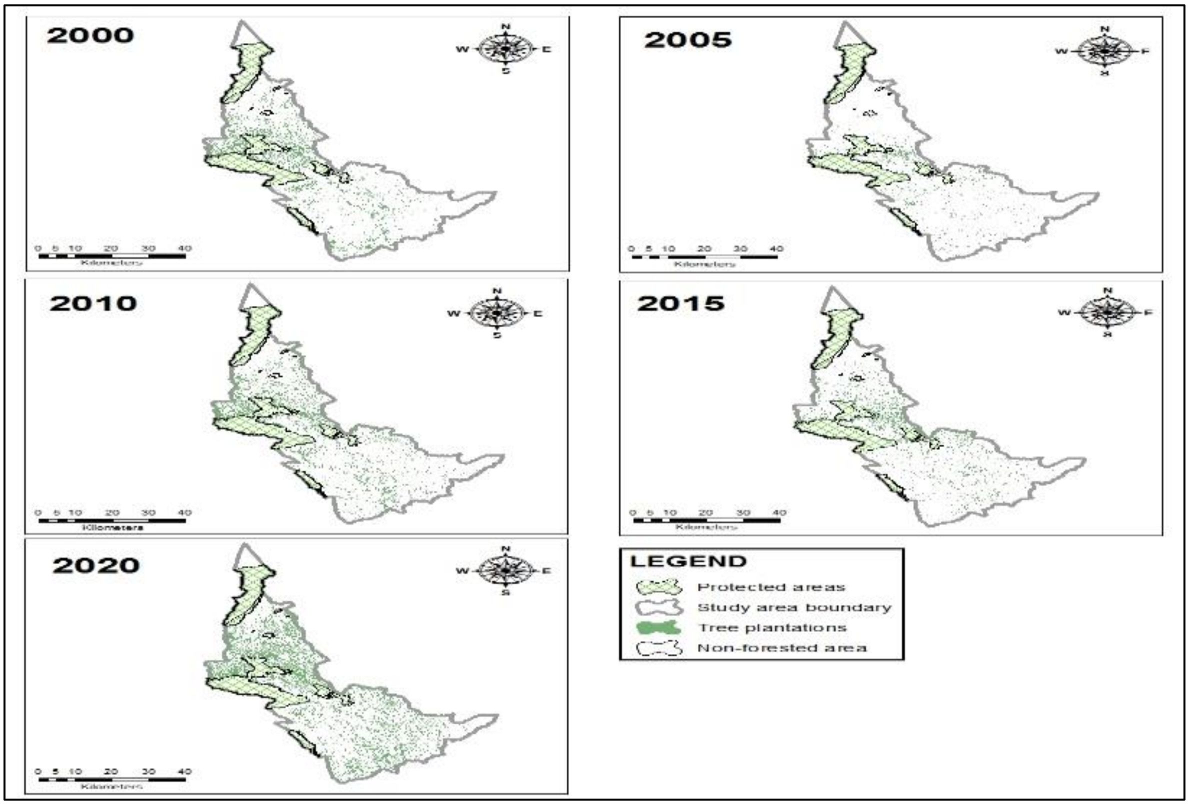
Figure 3: Landsat satellite image specifications used in land-use/cover classification Greater Kabale and Kanungu Districts



Source: (Satellite images, 2020).

Satellite images for Greater Kabale District and Kanungu are presented in *Figure 3* showing tree plantations growing. The image in the catchment land use/cover types is described based on field observations. Field observations were used as a basis for developing the image classification scheme through the categorisation of land use and cover classes. The scheme was customised because of the spectral reflectance of land use types and their distribution within the growing community.

The most dominant land cover types were found to be:

- **Tree plantations** which included all private areas covered by trees (not including protected areas).
- **Protected areas**: Forests and forest reserves
- **Non-forest areas** included all other land covers such as open water bodies, built-up areas, cultivated areas, grassland, and swamp.

These are descriptions of land use/cover classes used in capturing communities adopting tree planting in the Kigezi Sub-region of Kanungu and Greater Kabale Districts for image classification.

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This describes the changes in size and coverage of the tree plantation over the years from 2000-2020. This is clarified by the coverage and size of the tree plantations, as elaborated in *Table 3* below.

Table 3: Satellite images showing the magnitude of Forest plantations and non-forest coverage 2000-2020

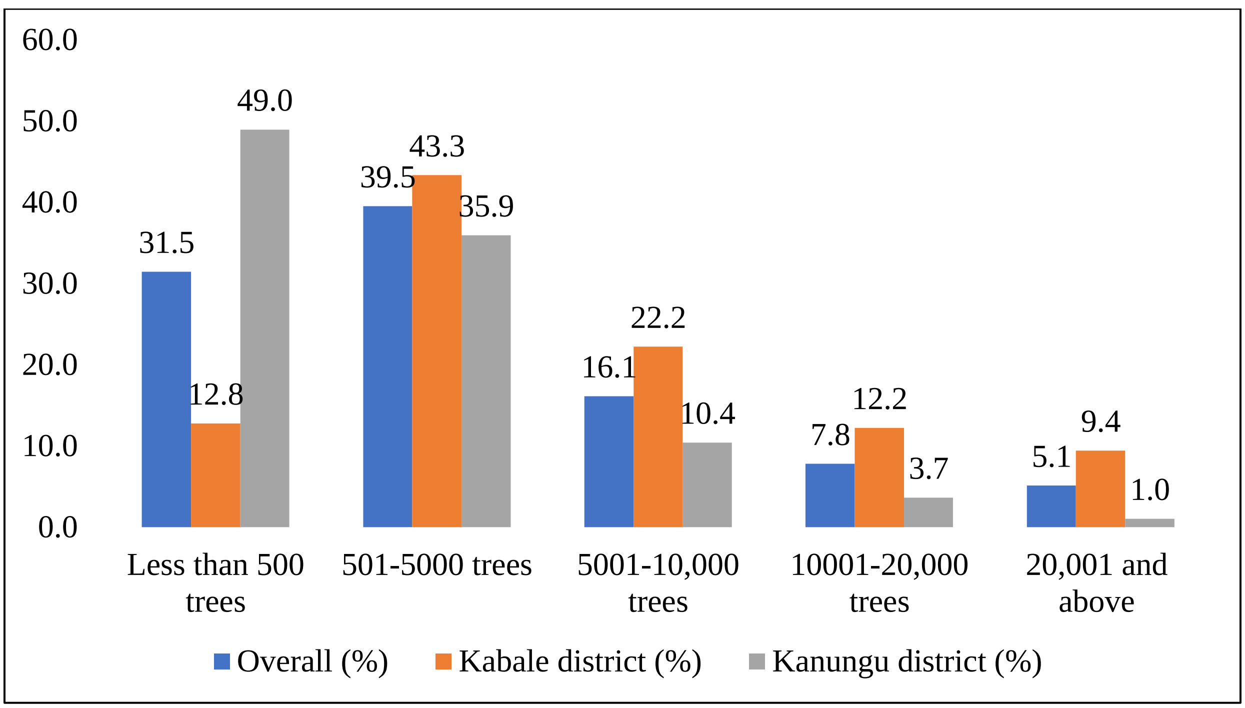
Years	Tree plantations/Forest/Non-Forest area coverage 2000-2020				
	2000	**2005**	**2010**	**2015**	**2020**
Tree plantations (ha)	34,502.04	12,849.85	35,946.37	24,047.86	63,873.66
Non-Forest areas (ha)	212,452.52	234,193.77	211,241.29	223,173.87	183,423.60
Forest Reserves (ha)	8367.18	8,273.12	8,124.08	8,085.01	8,004.48
Total area	257, 321.74				

Source: (Satellite images, 2020).

The Magnitude of Trees Plantations per Individual Farmers

The researcher further determined Tree plantation coverages using the field data. Trees plantations are usually planted at a distance of 3 times 3 meters to create space for the growth of a tree pruning and thinning that is usually done as trees gain canopy. The trees plantations owned were categorised according to the ranges shown in *Figure 4*.

Figure 4: Size of tree plantations



Source: (Primary data, 2020).

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The results show that the overall majority of respondents owned tree plantations in the range of 501-5000 trees and less than 500 trees at 39.5% and 31.5%, respectively. This implies that overall, 277 (70%) of the respondents who participated in the study own tree plantations of 5000 trees or less and are small-scale holder tree plantations. The same applies to the two districts where 168 (43.3 %) and 138 (35.9%) of respondents reported owning tree numbers in the range of 501 and 5,000 trees and 50 (12.8%) and 190 (49.0%) for trees less than 500 in Kabale and Kanungu districts (Turyasingura, 2022), respectively. However, across the two districts of Greater Kabale and Kanungu, it is evident in the figure that there are more tree growers in Kabale with more than 5,000 trees. For example, the figure shows that more than 154 (40%) of respondents in Kabale have tree plantations in excess of 5,000 trees. This is attributed to the land that has been bought and consolidated as tree plantations for commercial purposes only.

Given the number of trees that are planted on an acre of land (450 trees), it is evident that most tree farmers who participated in the study are small-scale tree growers (39.5%). The Kigezi Sub-region is known for its small and fragmented land. Therefore, most farmers are small-scale growers, whereas the remaining 20 (5.1%) are large-scale farmers and absent landlords. Nonetheless, for most absent landlords, it was revealed that they preferred to have trees rather than crops as a source of household income. This is considered a major challenge to the rural community because these landlords do not care to allocate most of their land for croplands, a major source of communal food supply and livelihood sustainability from tree planting. Indeed, to illustrate that many landlords have abandoned food crop production to purely tree production just for commercial purposes. Tree plantations and monocultures cover large hectares of land in different landscapes of the Kigezi Sub-region. The eucalyptus and pine tree plantations have transformed the land cover and use in the Kigezi Sub-region. This describes the changes in size and coverage of the tree plantation over the years from 2000–2020, as presented above.

CONCLUSION

There has been an increasing trend and extent of tree plantations in the Kigezi sub-region. The household land size and the income of the head of the household are the most important factors and characteristics that influence tree planting. Small-scale holders or landowners are likely to own tree plantations due to the high opportunity cost involved. This is in line with the planned behaviour theory, where people engage in any activity after weighing both the benefits and negative consequences. Therefore, the decision to plant trees will be largely determined by the degree to which one understands and addresses the factors which encourage or discourage him or her from planting trees and managing them.

Recommendation

According to the findings, sustainable forestry management (SFM) is recommended according to the tree species planted in the area and the changes over time. Policies regarding forest plantations and natural forests should pave the way for sustainable forest management. Sustainable forest management has kept the balance between three main pillars: ecological, economic, and socio-cultural. Succeeding in achieving SFM can provide integrated benefits to all, ranging from safeguarding local

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livelihoods to protecting the biodiversity and ecosystems provided by forests, reducing rural poverty, and mitigating some of the effects of climate change. As a result of the alarm about the harm that local people have experienced in their communities as a result of pine and eucalyptus expansion, policymakers at all levels must be mindful of the livelihood effects associated with tree planting initiatives and design corrective laws and programs to mitigate the challenges. For example, public education and sensitisation programs are necessary alongside other prohibitive laws to guard against unsustainable land use practices.

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