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# Spatial analysis of rural out-migration and land use change: A case of Western Uganda

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## ABSTRACT

This study evaluated the relation between rural-urban migration and land use changes at origin. The analysis was based on households (1015) data on their social and economic characteristics, which was used to map the spatial patterns of rural out-migration. Next, on the basis of Google-Earth imagery for 71427 ha and ground truthing, land use changes for the period 2000-2021 were assessed using a grid-based approach. The results revealed that rural areas with relatively high levels of out-migrants underwent strong intensification of land use with conversion of natural land covers to plantation forests, cropland and built-up land. This land use intensification was not in the communities with low out-migration levels. The relation was still significant if controlled for distance to the urban areas and population density level. From the study findings, we recommend that policy considerations for rural development in the study area and similar rural areas should integrate the association effects of migration on land use.

**Keywords:** Land use change, livelihoods, rural-urban migration, rural development, Uganda

## RÉSUMÉ

Cette étude évalue la relation entre la migration rurale-urbaine et les changements d'utilisation des terres à l'origine. L'analyse était basée sur les données des ménages (1015) concernant leurs caractéristiques sociales et économiques, qui ont été utilisées pour cartographier les modèles spatiaux de la migration rurale. Ensuite, sur la base d'images Google Earth pour 71427 ha et de vérifications sur le terrain, les changements d'utilisation des terres pour la période 2000-2021 ont été évalués en utilisant une approche basée sur une grille. Les résultats ont révélé que les zones

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rurales avec des niveaux relativement élevés de migrants ont subi une forte intensification de l'utilisation des terres avec conversion des couvertures terrestres naturelles en forêts de plantation, terres cultivées et terres construites. Cette intensification de l'utilisation des terres n'était pas présente dans les communautés ayant des niveaux de migration faibles. La relation était toujours significative si elle était contrôlée pour la distance aux zones urbaines et le niveau de densité de population. À partir des résultats de l'étude, nous recommandons que les considérations politiques pour le développement rural dans la zone d'étude et les zones rurales similaires intègrent les effets d'association de la migration sur l'utilisation des terres.

**Mots clés**: Changement d'utilisation des terres, moyens de subsistence, migration rurale-urbaine, développement rural, Ouganda

## Introduction

Land use in rural areas is rapidly changing in the global south (UNCCD, 2017). Land use change is a process by which human activities transform the natural landscape (Suratman and Ahmad, 2012). In sub-Saharan Africa (SSA), natural land is increasingly converted to agricultural and built-up land (Bullock *et al.*, 2021). Over half of the SSA countries are losing their natural land cover with average annual conversion rates ranging between 0.1 to 4%. Regeneration of natural land cover is taking place in only few of the countries (Figure 1).

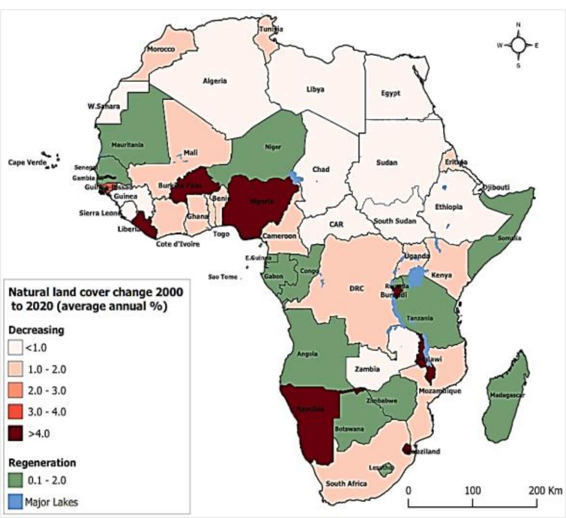



Figure 1. Percentage change in natural land cover in African countries for the period 2000-2020. Regeneration refers to the re-growth of natural land cover. Data Source: FAOSTAT 2021.

The conversion of natural land cover is driven by the interconnected influences of the changing climate, rapid population growth, and shifting socio-economic dynamics including migration and urbanisation (Bullock *et al.*, 2021). Impacts of the changing climate manifested through frequent and severe weather events including droughts, storms and floods contribute to land degradation and influence land use decisions (UNFCCC, 2022). A common discourse is that land degradation and population growth in rural areas add pressure on land use through increased food demand, resulting in extensification of agricultural production (Mwesigye and Matsumoto, 2016; MAAIF, 2020). Combined with the cultural practice of sub-dividing land among household members, population pressure leads to the fragmentation of household land into small plots that inadequately sustain land-based livelihoods. Amidst factors such as land degradation and productivity loss, the rural dwellers that cannot sustain their land-based livelihoods may migrate as a livelihood strategy (Tumwesigye *et al.*, 2021b). The migration of a household as a whole or its member(s) to seek an alternative livelihood in the urban economy can therefore be induced by land use changes in the rural areas of origin (Bhawana and Race, 2020). Rural out-migration is one of the demographic responses to resource scarcity in the context of population pressure and unstained livelihoods (Bilsborrow, 1992). However, rural out-migration can also influence land use change in the rural areas of origin (Göl *et al.,* 2011; Tran, 2019). The departure (especially of young adults) from rural areas and out of land-based livelihood activities can influence labour availability in their areas of origin. This contributes to changes in the rural livelihood activities and the associated land uses and land use practices. For example, Grau and Aide (2005), found that rural out-migration led to reduced pressure on agricultural land in developing countries through two mechanisms. In the short term, rural-urban migration creates scarcity of rural farm labour. In the long term, older cohorts retiring from farming lack replacement as their adult children migrate away. This leads to farm downsizing. On the one hand, this phenomenon can lead to dis-intensification of agricultural land use and land abandonment, as observed for example in Asia (Hussain *et al.,* 2016). On the other hand, the rural out-migrants reinvest in their areas of origin through remittances supporting land acquisition and land expansion/consolidation thereby leading to extensification of agricultural land and modification in land uses (Vanwey *et al.,* 2012). Extensification means increasing the area of land under agriculture activity (cultivation or livestock grazing) to meet growing food demands and the need to sustain land-based livelihoods. Whereas land use intensification broadly means increased use of a unit area of land, including changes between land use types (Martin *et al.,* 2018).

Land use extensification into, often (would-be) protected, natural areas (e.g. wetlands, natural forests) can contribute to their degradation (Stojanov *et al.,* 2017). Such interconnectedness depicts rural out-migration as both an inducer and an outcome of land use change (Tran, 2019; Figure 2). Overall, the mixed interactions of rural out-migration and land use change are still understudied in SSA (Gray and Bilsborrow, 2014). Nevertheless, SSA is increasingly characterised by a high population growth and rural densification, rural to urban migration and rapid urbanisation. Better understanding such linkages would offer new scopes for rethinking rural development (van Vliet *et al.,* 2020a). For instance, the view that rural out-migration leads to abandonment of agricultural land, rewilding and regeneration of degraded natural resources remains common in the rural development discourse (e.g. Obubu *et al.,* 2022). As a result, policies and management practices that consider rural to urban migration and land-use as separate issues are likely to miss important connections that would enhance the sustainability of rural livelihoods (Bell *et al.,* 2010). The sustainable planning, management and development of rural areas should therefore be framed within a context that integrates the demographic and socio-economic dynamics and their influence on land use.

Land and related natural resources including water, wetlands and forests are important resources to sustain rural livelihoods, household income generation, food security and rural development in developing countries (FAO, 2017). For instance, land-based activities such as arable farming, livestock production, forestry and fisheries are the main livelihood means of over 96% of the rural households in Uganda (MAAIF, 2017). Also, Uganda's GDP is generated mainly by exploitation of land and land-based natural resource. For instance, the agricultural sector, which is based on using the land-based natural resources contributed about 24% to 2020 GDP (UBOS, 2020). Given this functional role of land supporting economic activities for the rural household and the national accounts, the management of land and its use is crucial to ensure sustainable conditions. Effective land management requires understanding the evolving changes in land use and the influencing factors. Land use change can be

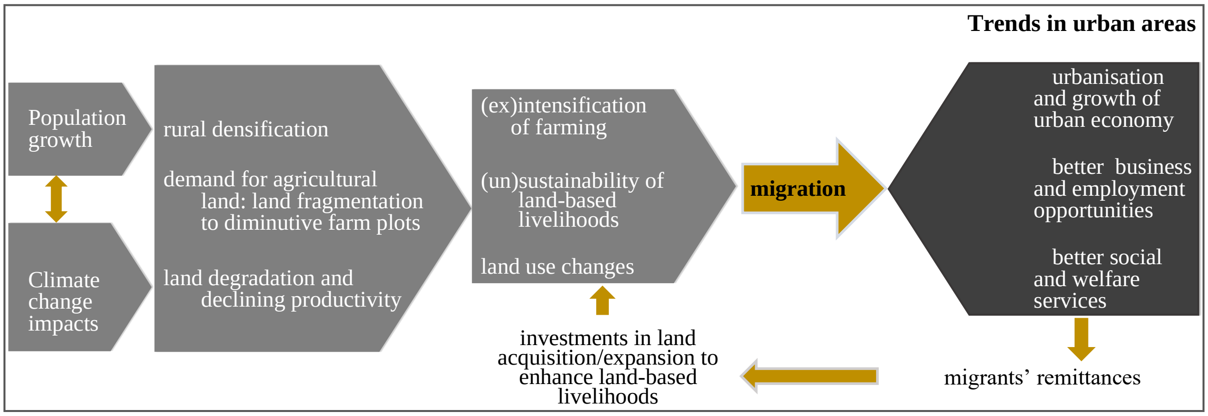



**Figure 2. Conceptual bi-directional connection between rural out-migration and land use change.**

influenced by population dynamics, among several factors. For example, increase in population may lead to increased demand for food. In the context of the study area, to meet such increased food demand would require either more land to be converted to cropland and grazing land or farming the existing agricultural land more intensively, thereby influencing land use. In cases where the extensive and intensive use of land can no longer sustain the rural land-based livelihoods, the household or its members may opt to migrate as an alternative livelihood strategy, (for example in Nepal, Bwahana and Race, 2019). It is such linkage of land use change and migration that is less studied in SSA in general. Particularly in Uganda, there are existing knowledge gaps in the migration literature, that are related to one, how migration, especially rural out-migration is related to land use change, and two, how future migration and demographic trends, for example, changes in demographic structure will impact the use of land in rural Uganda in the years to come (NPA, 2020).

In this study, we aim to better understand the linkages between rural out-migration and land-use change based on a quantitative spatial analysis. We are not testing the causal relationship between out-migration and land-use change because this relation usually also interacts with other causes, e.g. economic factors that are beyond our scope (Gray and Bilsborrow, 2014; Walters, 2016). Instead, we follow the conceptual understanding on the bi-directional connection between land use change and migration (Figure 2) and use this to explore and quantify possible links between migration and land use change. More specifically, this study spatially investigates whether rural out-migration correlates to intensification or extensification of land use in Uganda. Conceptualization is based on local knowledge of the demographic and social-economic trends in Western Uganda. Scheming followed the Driver-Pressure-State-Impact-Response (DPSIR) assessment approach. We explore this using western Uganda as a case study area. Like in other SSA countries, land use in rural Uganda is rapidly changing (Luwa *et al.*, 2020). Generally, natural land cover has decreased to make way for agricultural and various forms of developed land (UBOS, 2020a). Debates and policy discussions in Uganda attribute these land use changes to the fast-growing population and its associated socio-economic dynamics, including migration and urbanisation (NPA, 2020). Rural to urban migration is becoming widespread across the country and is one of the significant drivers for the ongoing rapid urbanisation (Tumwesigye *et al.*, 2021a). Most rural households consider out-migration as a viable livelihood option and send out their adult youths to seek work in the urban economy (Tumwesigye *et al.,* 2021b). This rural out-migration takes place and its potential consequences on land use may constrain the sustainability of rural land-based livelihoods and hamper efforts of rural development and poverty reduction (Selod and Shilpi, 2021; Meyfroidt *et al.,* 2022). Nevertheless, our empirical understanding of the consequences of rural out-migration on land use in SSA currently remains limited. This is particularly so for Uganda. To our knowledge, the nexus between rural-urban migration and land use changes has not yet been studied for this country. This results in gaps in terms of reliable data, but also in terms of empirically based insights that can underpin successful rural development policies, plans and practices.

The overall objective of this study is therefore to spatially examine the linkage between rural out-migration and land use change over the previous two decades. We hypothesize that higher susceptibilities to rural out-migration are associated with more intense land use change in the study area. We will test this hypothesis by answering the three specific questions below, which contribute to a better understanding of the consequences of out-migration on land use. We also generate knowledge to support rural policy and management decisions on sustainable land management, migration and rural development. The specific questions are:

1. What is the overall extent of land use change in the study area?
2. What is the spatial relationship between rural-out migration and land use change?
3. What are the on-going land use changes in areas with strong rural out-migration levels?

**Study area**

The study was conducted in the Ankole sub-region in western Uganda (Figure 3). The sub-region spans an area of about 16,100 $km^2$ made up of gentle rolling hills, shallow valleys and flat land. It is inhabited by an estimated 4.1 million people (UBOS, 2022), which is 10% of the total population of Uganda. The Ankole sub-region was selected as a study area because it represents a typical rural landscape frontier with natural land covers (including wetlands and forests), agricultural land and built-up land. More so, it is representative of many sub-regions in East Africa in terms of population growth rate (3.1%), population density (223 persons/$km^2$), rural-urban migration rate (11.2% between 2000 to 2020) and urbanisation level (27% in 2020). On the national level, the population growth rate, population density, rural-urban migration rate and urbanisation level are 3.2%, 229 persons/$km^2$, 11.6% and 25% respectively (UBOS, 2021).

The sub-region consists of 12 districts (Buhweju, Bushenyi, Ibanda, Isingiro, Kazo, Kiruhura, Mbarara, Mitooma, Ntungamo, Rubirizi and Sheema) and is predominantly rural. However, it also has a significant and expanding urban structure. The main urban centres are Mbarara city (about 221,000 inhabitants), five fast-growing municipalities with a population size of at least 150,000 inhabitants, and 31 town councils with a population of at least 15,000 inhabitants (UBOS, 2021). Located about 267km southwest of the Ugandan capital Kampala, Mbarara city is a major town in the study area and serves as the regional capital (Figure 3). Also, the municipalities, and town councils serve as centres for administrative, social, and economic services. They host the decentralised and local government offices of the constituent districts, the health and educational institutions as well as various economic infrastructures (i.e. industries, factories, banks, and markets) (MoFPED, 2018). As such, Mbarara and these urban centres offer better opportunities for economic participation in both the formal and informal economic sectors. They therefore act as attraction poles for rural out-migrants (Tumwesigye *et al.,* 2021a). This is also evident from recent land cover changes. For example, Mbarara's area has expanded from 55$km^2$ in 2000 to 440$km^2$ in 2020 (authors' computation based on Google Earth Imagery). Urbanisation in Uganda typically happens through horizontal expansion and area reclassification, leading to land use conversion of peripheral agricultural land into built-up urban land.

Rural areas, however, are dominated by agricultural land. Most of this land is owned by smallholder farming households that own on average 3 ha (MAAIF, 2020). The settlement pattern consists of scattered built-up homesteads of families who reside on their farmland. There are no clustered settlements. The scattered rural homesteads are served with a network of roads. The road network enables access to the urban-based social and economic services, including education, healthcare and markets for agricultural produce and other goods.

The majority (89%) of rural households are engaged in subsistence agriculture as their main source of income (UBOS, 2021). Mixed crops and livestock farming - mostly bananas and coffee, and cattle – is common in all districts, except Kiruhura and Ibanda. The latter districts are dominated by livestock farming. Livestock smallholder farmers keep on average a herd of five animals on natural grassland in paddocks or under extensive communal grazing (MAAIF, 2020). In the Bushenyi and Buhweju districts, a few farmers are undertaking commercial tea growing. In these two districts, there are also four rural-based tea-processing factories that offer employment opportunities. Other agriculture-based factories (including for milk and coffee processing) are concentrated in the district municipalities. Buhweju district also has mineral deposits (mainly gold, tin, and kaolinite), making artisanal mining one of the economic activities. Although the rural population can somewhat diversify their household income generation with off-farm labour, trade and business, the majority of households (76%) largely depends on land-based livelihood activities. The Ankole sub-region is the centre of agriculture production, commercial and industrial activities in western Uganda.

## Materials and Methods

**Assessment of rural out-migration likelihood.** We used primary data obtained from household surveys in the 12 districts of Ankole sub-region. The household survey was conducted between February and August 2019. We collected data on the demographic, social and economic characteristics of the households and the biophysical, social and economic characteristics of rural communities in the study area. The surveys were conducted in at least three randomly sampled Parishes per Sub-County in the study area: a Sub- County is a collection of, on average, 5 Parishes. We surveyed at least 3 households per Parish. The sample size per Sub- County was proportional to the corresponding number of households. A total of 1015 households consisting of 7612 household members were surveyed. The determination of the total sample size for each Sub- County followed a modified Cochran formula on sampling (Bartlett *et al.,* 2001). Details on sampling and data collection can be followed in the authors' previous publication titled 'who and why rural out-migration in Uganda' (Tumwesigye *et al.,* 2021b). We used the survey data to assess the likelihood of out-migration through logistic regression modelling. The survey data was split into 2 sub-data sets: 80% to allow model fitting and estimation of the likelihood out-migration and 20% to allow model validation. We obtained the household demographic, social and economic characteristics, and the community level biophysical characteristics and fitted them as control variables for the likelihood of rural out-migration. The fitted logistic regression function (n = 7612) took the form (Tumwesigye *et al.,* 2021b):

Probability(rural out-migration) = **exp(**$0.45 + 0.03\ household\ size - 0.97\ dependency\ ratio + 0.45\ literate$ and $skilled + 0.58\ occupation\ as\ formal\ employment + 0.02\ years\ in\ occupation + 0.13\ household\ land\ size + 0.57\ household\ income - 0.38\ diversified\ income\ sources - 0.46\ standard\ of\ living - 2.25\ satisfaction\ level\ with\ quality\ of\ public\ services$ - $0.62\ distance\ to\ a\ municipality + \varepsilon_i$) /
**1+ exp(**$0.45 + 0.03\ household\ size - 0.97\ dependecy\ ratio + 0.45\ literate$ and $skilled + 0.58\ occupation\ as\ formal\ employment + 0.02\ years\ in\ occupation + 0.13\ household\ land\ size + 0.57\ household\ income - 0.38\ diversified\ income\ sources - 0.46\ standard\ of\ living - 2.25\ satisfaction\ level\ with\ quality\ of\ public\ services$ - $0.62\ distance\ to\ a\ municipality + \varepsilon_i$) (1)

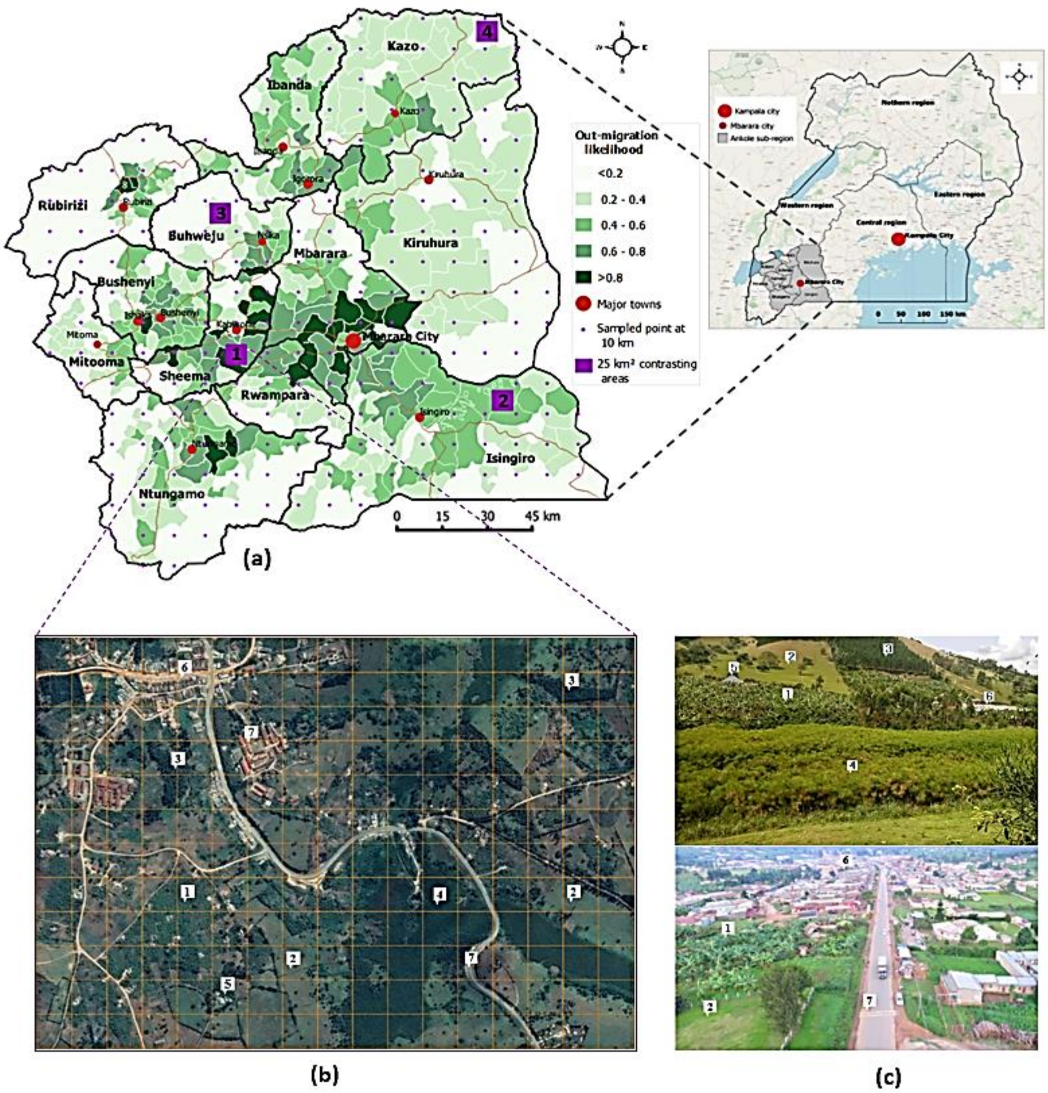



**Figure 3: (a)** Ankole sub-region in western Uganda showing rural out-migration level at parish spatial scale in the 12 districts.

We applied the fitted final logistic model to the validation sub-dataset (n=1520), generated a receiver operating characteristic (ROC) curve and interpreted the area under the ROC curve (AUC) (also see, Tumwesigye et al., 2021b). Relying on the robustness of the fitted logistic model in estimating the likelihood of out-migration, we used the generated coefficients to quantify the level of out-migration likelihood. For each sampled parish, the average corresponding out-migration likelihood was computed. We also computed the average out-migration likelihood at Sub- County level and considered it as a representative level of out-migration likelihood in the remaining Parishes that were not surveyed. Then, we thematically mapped the out-migration levels and created an out-migration likelihood map (Figure 3a). Points 1,2,3 and 4 are the sampled contrasting areas with >0.6, 0.4-0.6, 0.2-0.4 and <0.2 rural out-migration levels respectively; **(b)** Google Earth image (March 23rd 2021) showing part of a sampled landscape in the study area with an overlay of 1ha grid cell framework, and **(c)** Photos illustrating a typical study area landscape showing dominant land use types namely: 1-Crop land; 2-Rangeland/Livestock farm; 3-Plantation forest (Eucalyptus); 4-Wetland (Papyrus swamp); 5- Rural Homestead; 6-Urban built-up land; 7-Public infrastructure-road, school. Source: Google Earth and field photographs by the author.

**Quantifying land use change.** We detected land use during the period 2000 – 2021 on the basis of Google Earth imagery using a grid-based spatial analysis approach. To examine land use change and its linkage to rural out-migration, we had to generate representative datasets on land use types for areas with different levels of out-migration probability and for different moments. For this, we made a spatial gridded analysis of satellite imagery available in Google Earth Pro (see e.g. Ramsdale *et al.*, 2017). Two land use sampling strategies were conducted: first, where broader areas at four locations were analysed in detail and second, where land use changes were assessed for a large number of smaller areas across the study area (Figure 3a).

For the first sampling strategy, we randomly selected and delineated four contrasting areas (each measuring 25 $km^2$) on the out-migration likelihood map of the study area (produced based on the logistic regression in section 3.1). The contrast was based on the out-migration level: that is rural areas with less than 0.2; 02-04; 04-0.6 and above 0.6 levels. Next, we traced the extent of each delineated contrasting area and constructed a grid with cells measuring 100 m by100 m (1ha) in QGIS (version 3.4). The resultant grid vector layer (see also figure 3b) per contrasting area had a total of 2500 cells. We chose a one hactare grid framework in this study so as to achieve a fine visibility while examining the land use types. In addition, the one ha grid framework aligns well with the average land holding per rural household in the study area, which is 3 ha (UBOS, 2020a). This meant that we made on average thrice the number of observations per household. We were therefore able to take into consideration the diverse land uses, even for an individual household, commonly associated with the land-based rural livelihood activities. After this, we overlaid the grid vector layer onto the google earth imagery and assessed the dominant land use type in each grid cell. We used Google Earth imagery because it gives a continuous earth image coverage at sufficient resolution (minimum 0.5 m/pixel) and this allowed reliable identification of the land use type. We identified the dominant land use type through visual inspection of each grid cell at full resolution. Starting with the top-left grid cell, we systematically and sequentially moved from one cell to the adjacent cell while recording the dominant present land use type in the corresponding attribute table. For each grid, we repeated this land use type classification for three moments: September 23rd 2000, November 18th 2010 and March 23rd 2021.

These were the moments of no / minimal cloud cover and probably the periods with high resolution images. We did this for all the four contrasting areas, resulting in a total assessed area of 10,000 ha. Finally, we established the land use changes over the past two decades (2000 – 2021), by comparing the dominant land use of each grid cell for the three image dates. To enhance visualisation and interpretability of these temporal-spatial land use changes, we created thematic grid maps showing the spatial distribution-field of the different land use types (Figure 5). We undertook ground truthing to assess the accuracy of our land use classifications. For this, we conducted a field visit to the four contrasting areas and cross validated the identified land use types based on Google Earth imagery with the (on ground) field observations in 2021 (Figure 3c). In total, 80 sampled locations (20 per contrasting area) were cross-validated this way and a confusion matrix was computed to quantify the accuracy for the classified land uses (see e.g. Johnson, 2006). Overall, this grid-based spatial analysis approach provided a consistent way to collect detailed information on land use change. However, the approach was also very labour intensive, limiting the geographical scale that could be mapped this way. We therefore applied a second sampling approach, based on similar mapping protocols. We aimed at having a sample size that is statistically representative of the Ankole sub-region. Here, we aimed to further examine at a wider spatial scale the linkage between land use change and out-migration levels. We also aimed to establish the overall extent of land use change in the Ankole sub-region. Considering the geographical scale of the study area, we adhered to the following sampling approach. At every 10 km, we constructed a 6x6 framework of 1ha grid-cells (36 ha per site) and manually classified for the dominant land use type of each cell, based on visual inspection. A total of 13,536 ha at 376 individual sites were assessed this way. Each site was mapped three times (i.e. in 2000, 2010, and 2021). This regular sampling approach ensured that our dataset was representative for the Ankole region as a whole. Yet, one of its limitations was that relatively few observations corresponded to areas that are highly susceptible to rural out-migrations (given the limited spatial extent of these areas). We therefore also assessed the extent of land use change in areas with high susceptibilities to rural out-migrations (above 0.6 level), resulting in an additional 47,891 ha mapped. This was done for the period 2010 to 2021. Overall, a total of 71,427 ha in Ankole sub-region were mapped for land use change.

## Results

**Dominant land use types and their change**. Based on our spatial gridded approaches and field truthing, we identified eight dominant land use types in the Ankole landscape: crop fields, rangeland, plantation forests, wetlands, natural forests, rural homesteads, urban built-up land and public infrastructures (Table 1; Figure 3b, c). The confusion matrix from field truthing revealed 98% accuracy level (correctly identified land use types). This accuracy level is greater than the basic minimum (85%) requirement for digitally identified images (Paul, 1991) in spatial analysis studies. Therefore, the identification approach was found reliable and practically useful for the purpose of this study. The occurrence of each land use type between 2000 and 2021 is shown in Figures 4.4 and 4.5, which is based on the assessment of 13,536 ha: from 36 ha sites mapped at every 10 km across Ankole sub-region. Generally, Ankole landscape is dominated by rangeland (about 60%) and crop fields (about 28%). These are followed by plantation forests (5%), wetland and natural forest cover (5%), and developed land (2%). We consistently observed this dominance trend during the study period (the past 21 years, since 2000).

**Table 1**. Description of the dominant land use types in the study area.

| **Land use type** | | **Description** |
|---|---|---|
| Crop fields | Agricultural land | Land covered with perennial and annual crops |
| Rangeland / Livestock farm | | Land dominantly covered with grasses and shrubs for livestock grazing |
| Plantation forest | | Land covered with a monoculture of planted trees (mainly Eucalyptus), commonly on small areas of 0.5-1 ha in the study area |
| Wetland | Natural land cover | Areas covered with marshy swamps (with often papyrus) |
| Natural forest | | Land covered with dense canopy of trees |
| Rural homestead | Developed land | Area with a constructed house as residential unit, scattered in the rural areas |
| Built-up urban | | Area with concentrated housing units in the delineated urban centres |
| Public infrastructure | | Land constructed with structure for the delivery of public services, including roads, markets, schools |

*(a): Crop (Banana) field*

*(b): Livestock farm, with crop (banana) field in the background*

*(d): Crops (coffee and Banana) field*

*(C): Eucalyptus plantation*

*(e): Rural landscape, with crop fields; rangeland; road; wetland (papyrus swamp)*

*(f): Rural homestead, surrounded by eucalyptus plantation; crop (maize & banana) fields*

Figure 4: Field Photos showing the dominant land use types in the study area. Source: Field photos taken by the author.

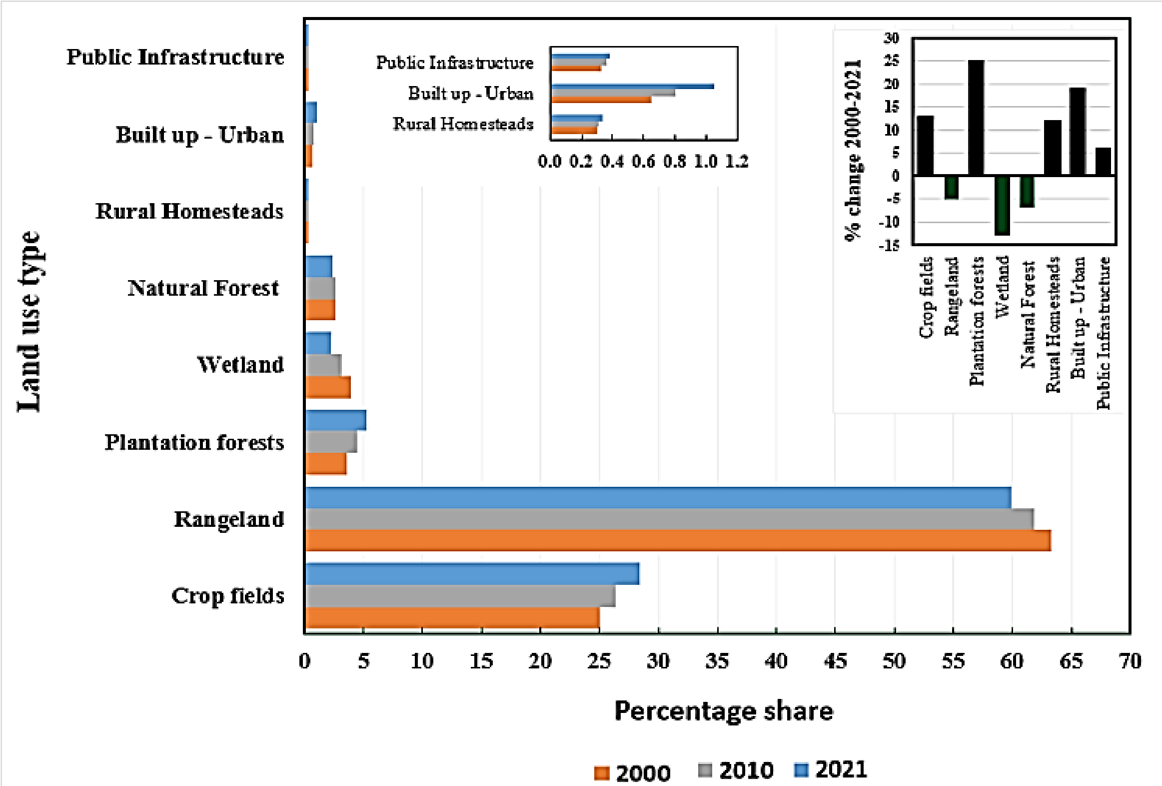
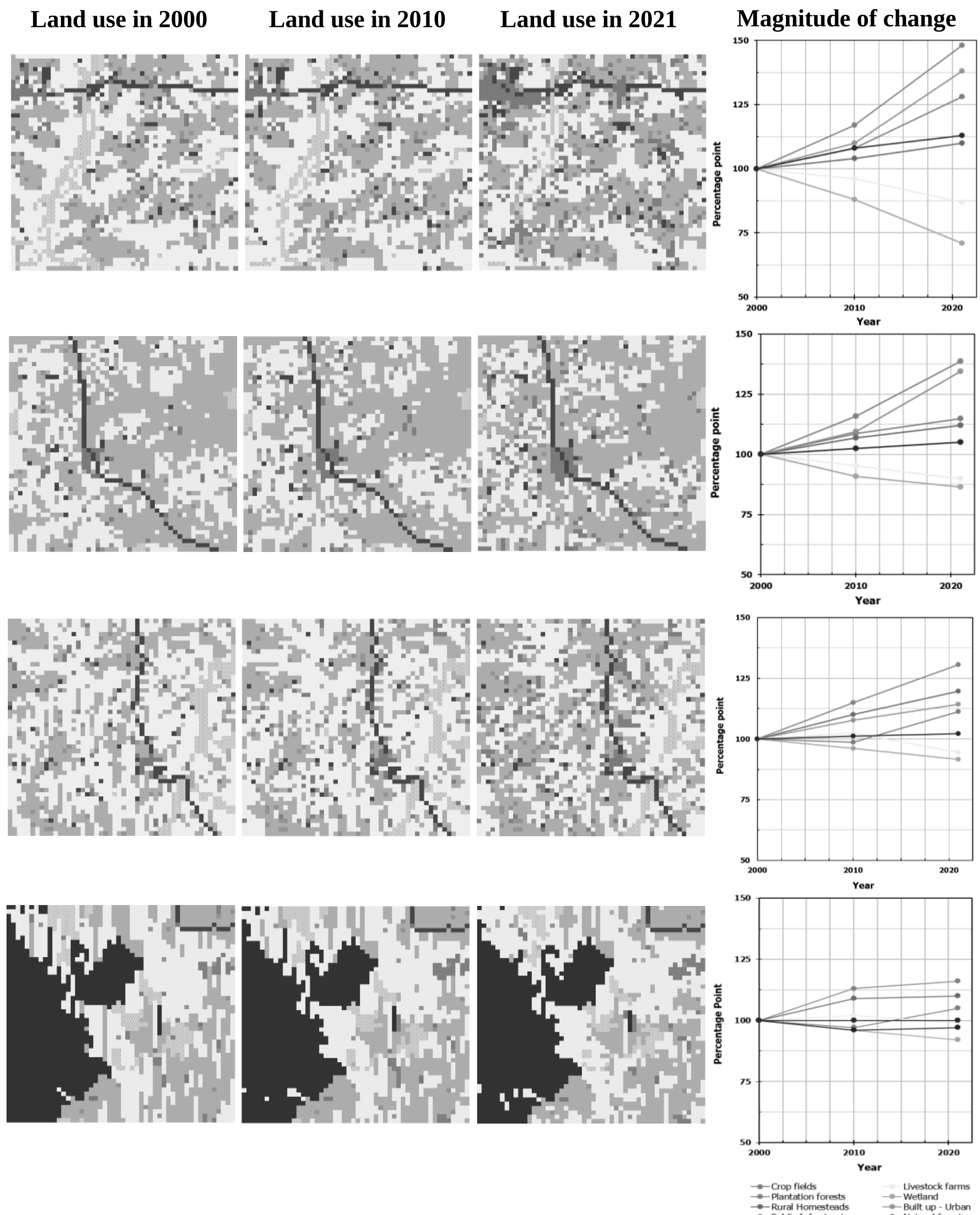



Figure 5. Percentage share of the dominant land use types in the study area (n=13,536 ha, from 36 ha sites mapped at every 10 km across Ankole sub-region landscape). Inset is the percentage change during the study period (2000 to 2021). We observed changes in all the land use types in the study area (Figure 5, inset). Although the agricultural land remained dominant over the past 21 years, the rangeland decreased by about 5%, whereas the frequency of crop fields increased by about 13%. There was continuously increase in area covered by plantation forests and this land use category had the biggest change margin of about 25%. We computed the percentage change in reference to the area share in 2000. We observed a reduction in the natural land cover with a decrease in wetland and natural forest by 13% and 7% respectively. Moreover, we noticed a general increase in the developed land especially the urban built-up land that sharply increased by about 19%. We observed this spatial pattern of land use change occurring scattered across the Ankole landscape. Results from assessing the contrasting areas (10,000 ha) (Figure 6) showed a similar trend of gradual decline in wetland and rangeland, while the cropland, plantation forest and built-up land increased in the past two decades. Overall, these changes are reshaping the spatial pattern of land use in Ankole sub-region into a mosaic of crop fields, planted forests and built-up urban land. Linking land use change with rural out-migration Figure 6 shows the land use changes in the sampled four contrasting 25 km2 areas with different levels of rural out-migration. Overall, between 2000 and 2021, there was a decrease in wetland and an increase in cropland and developed land in each of the contrasting areas. For the last two decades, the rate of change was relatively steady for each land use type in all the contrasting areas. Moreover, the magnitude of percentage change in the last decade increased, with relatively higher rate of change in areas with high levels of out-migration than in areas with less out-migration (Figure 6).




**(a): Sampled rural area with above 0.6 likelihood of out-migration**
**(b): Sampled rural area with 0.4-0.6 likelihood of out-migration**
**(c): Sampled rural area with 0.2-0.4 likelihood of out-migration**
**(d): Rural area with below 0.2 likelihood of out-migration**

**Figure 6:** Gridded land use maps and rate of land use change for the four contrasting areas for the years 2000, 2010 and 2021 (n=2500 ha for each contrasting area). See location of the contrasting areas in Figure 3.

We noticed high magnitudes of land use change in communities with ≥ 0.6 out-migration levels (Figure 6 a). On one hand, there was a continuous sharp increase in planted forest land, urban land and cropland, since the year 2000. The rate of change for these three land use types more than doubled in the last decade. The plantation forests had the highest rate of change (at +2.5% per year) compared to the other land use types. The public infrastructure and built-up rural homesteads also continuously increased, although the change was gradual throughout the study period. On the other hand, the wetland and rangeland continuously decreased. The rate of wetland loss was larger compared to the other land use types in the last two decades. The wetlands declined at an annual average rate of 1.4% for the period 2000-2010, which accelerated to 2.2% per year in the last decade. The communities with low to moderate (< 0.4) out-migration levels also had a gradual change in all the land use types during the study period (Figures 4.5c, d). Notably, the cropland decreased, while the rangeland increased during the period 2000-2010: contrary to the pattern noticed in communities with high out-migration levels. The changes in spatial distribution of land use types in these contrasting areas revealed a trend of gains and losses. For instance, plantation forests predominantly emerged in areas of wetland loss in communities with high (> 0.6) levels of out-migration (Figure 6a). Whereas, in communities with low out-migration levels (< 0.4), the wetland frontiers were gradually dominated by rangeland and crop fields (Figures 4.5c, d). The loss in natural forest cover was predominantly taken up by rangeland (Figure 6d). Such differences in the spatial pattern of land use changes in areas with different rural out-migration levels, suggest a linkage between out-migration and land use change. To further test the linkage, while understanding the need for a representative sample, we based on the 13,536-ha mapped at every 10 km and assessed the patterns of land use changes in the entire Ankole sub-region. From this, we detected the relationships between land use change and rural out-migration (Figure 6a). We also detected the association between land use change and changes in population density (Figure 6b). The temporal trend of land use change in the last two decades showed continued significant land use changes at higher levels of out-migration.

The association effect between land use change and out-migration levels in the study area, denoted by the R-squared, was strong for all the land use types (Figure 6a). Between land use change and population density, the association effect particularly for wetland, crop fields and rangeland, was relatively weak (Figure 6b). Comparatively, the magnitude of association, depicted by the slope of association (coefficients), were stronger between land use change and rural out-migration levels than for population density (Figure 6). This implies that changes in out-migration level affects land use change stronger than changes in population density in the study area. Overall, we observed a stronger degree of association between land use change for the out-migration levels compared to population density levels. The degree of association was notably stronger for plantation forests, crop fields, built-up land and wetland. This suggests that rural out-migration may be strongly affecting these land use types, more than any other, in the study area. Overall, the pattern in land use change across the sub-region, remained consistent to the pattern noticed in the four sampled contrasting areas. The results on land use change in the sub-region revealed a continued increase in land use for plantation forests, cropland and urban expansion on the one hand, and a decline in the natural land cover on the other hand, as out-migration increases (also see Figure 7). Notably, the change pattern in agricultural land showed gains for the cropland and gradual decline in the rangeland with increase in out-migration.

It was generally noticed that there is intensification of land use with increment in out-migration level. These changes are mainly towards expansion of cropland, planted forests and urban area, as well as a decline in natural land cover.

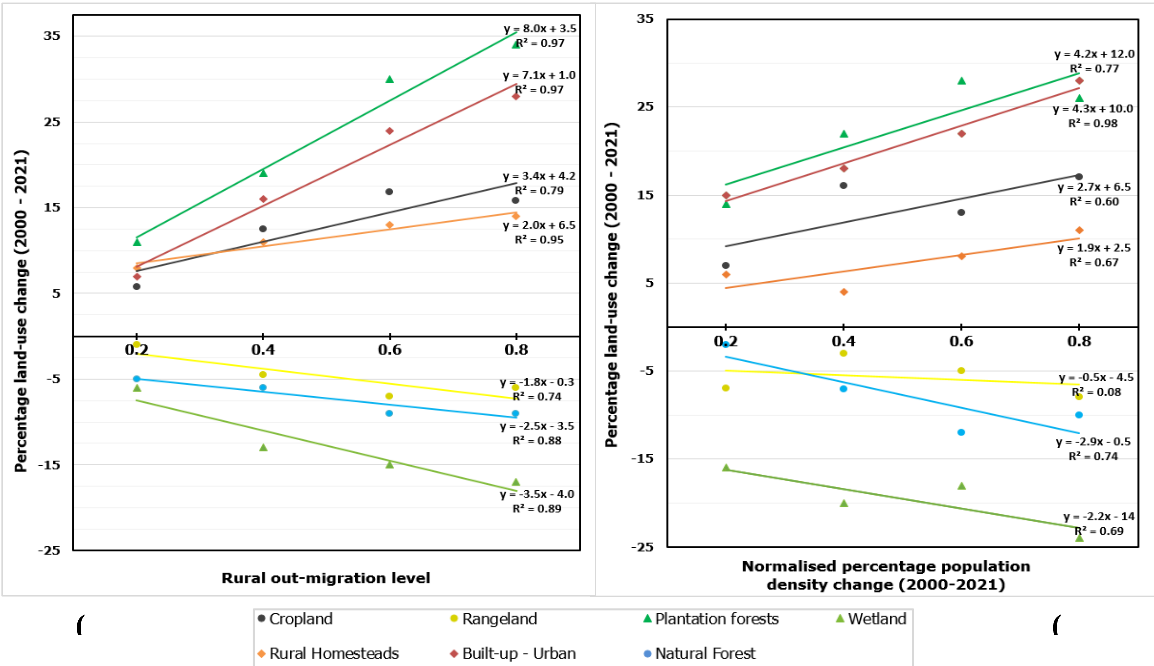



**Figure 7**: Association between (a) out-migration and land use change (2000-2021) and (b) population density and land use change in rural Ankole sub-region (n=13,536 ha); $R^2$ shows the degree of association.

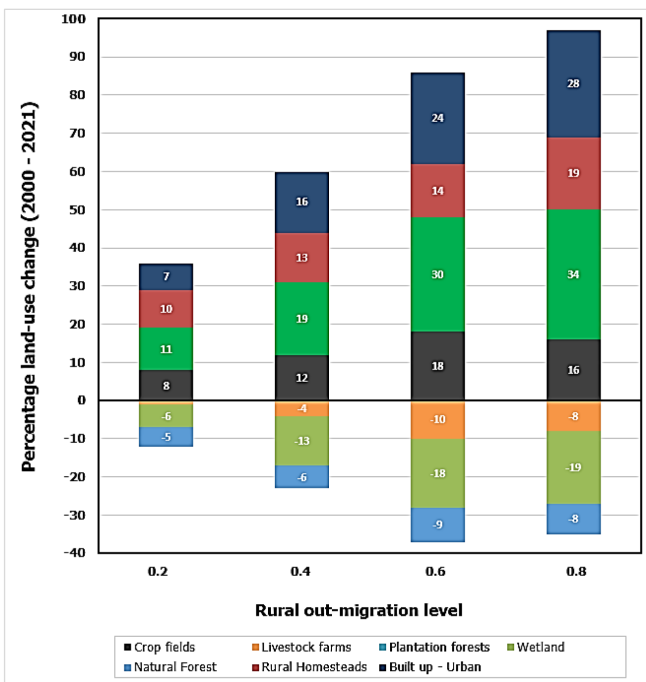



Figure 8: Total conversion rate for the dominant land use types in Ankole sub-region per rural out-migration level.

**Detailed land use change in areas with high out-migration level.** We assessed in detail the land use conversion pattern in all communities with high (> 0.6) level of out-migration for the entire Ankole sub-region in the last decade (Figure 9). Plantation forests, cropland and built-up urban area had the big net area gain, whereas wetland and natural forest had zero area gain. Cropland gained mainly from rangeland (about 74%), in addition to gaining from plantation forests (9.9%), natural forests (12.1%) and wetlands (4%). Interestingly, rangeland also significantly gained from cropland, implying inter-conversions within the agricultural enterprises. About 54% of wetland loss and 67% of natural forest loss were converted into rangeland. Further, the loss in natural forest cover (about 28%) was taken up by crop fields in the last decade. In some communities, plantation forest lost to farming activities whereas in other communities the rangeland and crop fields respectively contributed about 86% and 8% of the gained planted forest area. This is another form of land use type inter-conversion. Plantation forest cover also claimed about 30% of the wetland loss. The assessment didn't show any area (ha) of natural land cover restored during the study period. There were gains in built-up area in the last decade, with rangeland contributing 94% of the gain.

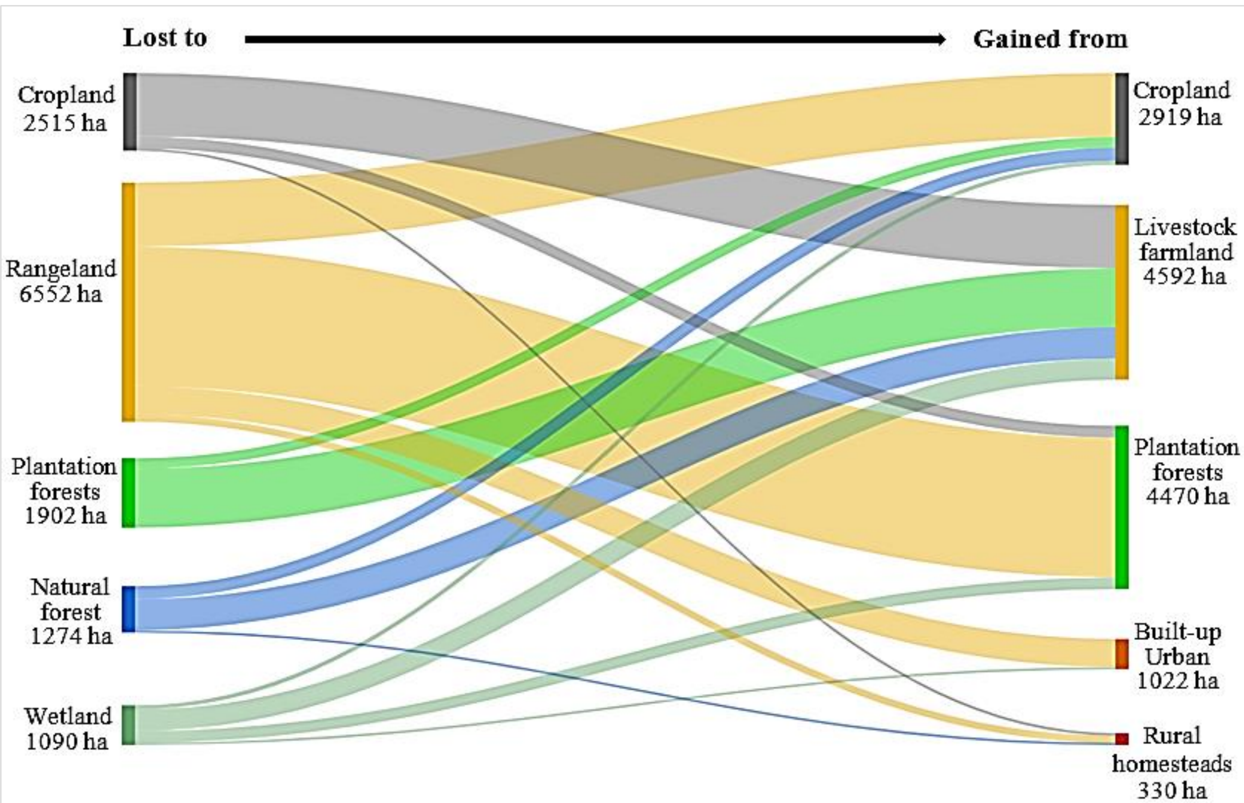



Figure 9**:** Sankey plot presenting gained/lost area (13,333 ha) for the corresponding land use type in communities with above 0.6 rate of out-migration (n=47,891 ha) for the period 2010 to 2021. The size of the flow shows a proportional share of area (ha) gained/lost.

Generally, communities with high likelihood levels of out-migration (> 0.6) are characterised with intensive land use changes (Figure 9), with remarkable losses in natural forest and wetland cover on the one hand and gains in plantation forest, crop land, and built-up area on the other hand.

**Discussion**

The dominant forms of land use in the study area are related to the rural household's livelihood activities, and to the rapid rural urbanisation phenomenon taking place in Uganda. Over 96% of Uganda's rural population depend mainly on smallholder farming activities, and therefore depend on land, to generate household income and maintain their livelihoods (MAAIF, 2020). Most households in the study area are involved in mixed farming activities, thus making cropland and rangeland the dominant land use types. These activities require farm infrastructures, generating a continued on-farm demand of wooden construction materials. This often influences farming households to establish their own plantation forests to ensure affordable and steady supply (UBOS, 2020a). Additionally, plantation forests supply fuelwood and act as 'living bank accounts' to be harvested when there are cash needs. There is also increased demand for timber used in building construction in the urban centres (UBOS, 2020a). The importance of plantation forests in supporting farming activities and as an alternative means for income generation could explain their dominance in the study area. Ankole is one of the sub-regions in Uganda with a high rural population base (about 3.3 million people) that is also fast growing at 3.1% yearly (UN-Habitat, 2021) leading to continued densification of the rural communities. Increase in human population directly increases the demand for built-up land for settlements and infrastructural development. This may explain the gradual increase in developed land with built-up homesteads and infrastructures related to public services in the study area. Additionally, rapid population growth generally increases food demand. With the rural population density already at 223 persons/km$^2$ in the study area, combined with a decreasing land size per capita in Uganda (FAO, 2020), there is increased pressure on the land to meet food demands and to sustain the household land-based livelihood activities. This may therefore contribute to the increased use of land for agricultural production.

Furthermore, Tumwesigye *et al.* (2021a) noted that the urban structure in western Uganda was already expanding faster than any other region since 2002. Typically, urban area expansion in Uganda is horizontal, spreading into the peripheral usually agricultural land (MoLHUD, 2017), implying direct land use change. Apart from the direct conversion of land to urban use, urbanisation can also indirectly influence land use for agriculture to match food production with food demand from the increasing urban population and for plantation forest (Eucalyptus) to satisfy the needs for timber and construction wood. Most food consumed by Uganda's urban population is sourced from the country's rural communities (Mackay, 2019). Generally, the changing use of land in western Uganda can be explained by the socio-economic processes linked to human population growth, urbanisation, and the interplay of human activities including the desire to sustain food production and the agriculture-based livelihoods. This study revealed an increasing trend in the rate of land use changes in association with rural out-migration levels. Considering that migration is driven by population densification, the already population pressure might explain the observed higher rate of land use change. This observed stronger association suggests that out-migration from the rural communities in Ankole sub-region possibly intensifies land use changes, contributing to reduced livestock farming, encroachment on wetlands, increased crop cultivation, establishment of tree plantations and increased built-up area. Another possible explanation could be that the out-migrants are sending remittances, which perhaps are invested by the recipient households into possibly either land acquisition or consolidation thereby changing the land use forms. UBOS (2019) reported that 13% of the households in the rural Ankole sub-region had received remittances from their urban-based social networks. A study on agriculture and remittances in Uganda (Veljanoska, 2014) found that remittances were used to support specialisation into low-risk farming enterprises such as cultivation of perennial crops, considering that Ugandan agriculture production is mostly rain-fed. More so, the migration of young adults from the rural communities to urban centres potentially decreases labour availability in the rural farming communities and may lead to a shift of agriculture production into less labour-intensive farming enterprises (Sloan, 2007), as the management of agricultural production increasingly depends on the ageing and elderly population. Such indirect influence of rural out-migration on land management and land use may therefore explain the gradual increase of plantation forests, and the decline of rangeland in the study area. Further still, the 'absentee landlords'- the migrant urban dwellers - may opt to put their share of family land under less labour demanding farming enterprises such as plantation forests (L'Roe and Naughton-Treves, 2017). Moreover, because of social connections and family ties, out-migrants may spend on upgrading their family houses or build larger modern houses that serve as status or wealthy symbols (Vanwey and Guedes, 2012). This may account for the steady increase in built up land under homesteads in communities with high out-migration levels.

Overall, out-migration is strongly associated with land use change in the study area. The gradual transformation of western Uganda landscape to a mosaic of cropland and planted forests, punctuated with expanding urban centres could, among other factors, be influenced by the direct and indirect effects from rural out-migration that is taking place.

## Conclusions

This study revealed sustained patterns of land use changes, and a strong association between land use change and rural out-migration in western Uganda. For the past decade, there has been intense land use changes in communities with relatively high rural out-migration levels. Cropland, planted forests and urban built-up land are on a continuous increase while wetlands and natural forests are on a decline. Continued loss of natural land cover, especially the wetlands, may limit provisioning of their ecosystems services and this exacerbates water (both quantity and quality) and soil degradation in the farming communities. In-turn, this potentially impacts the productivity of dependent farming activities and would lead to a reduction in household income from farming. The affected households that eventually find it untenable to sustain their farming-based livelihoods may induce rural out-migration as a coping strategy. Thereby introducing a cyclic effect of migration on land use change: both as an outcome and inducer of land use change. Therefore, considering the pattern and magnitude of natural land cover loss revealed by this study, we recommend that the district governments in Ankole should strengthen the enforcement of laws governing physical planning, nature conservation and land use management in rural areas, particularly in communities with relatively high levels of out-migration. Additionally, policy and practice considerations for rural development in western Uganda should integrate the association effects of migration on land use. Given that there is increasing loss of natural land cover, awareness amongst the rural population on the benefits from natural forest and wetland conservation and their sustainable use should be promoted. Public investments should be steered towards landscape management approaches that integrate demographic developments such as rural out-migration. The study area is representative of other sub-regions in East Africa therefore, the study results may also help understanding land use changes in other similar regions of East Africa.

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