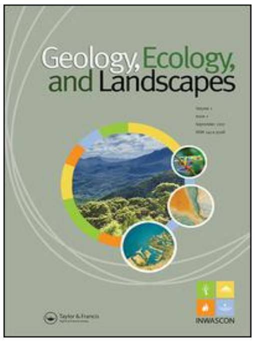

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RESEARCH ARTICLE

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The paradox of the land use/land cover change in Kipengere ranges in southern highlands of Tanzania

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ABSTRACT

This article examines spatial dynamics in Land Use/Land Cover (LU/LC) change in Kipengere ranges in the southern highlands of Tanzania. Though humans have been modifying land to obtain food and other essentials for thousands of years, the current trends, extents, and intensities of land-use change are far greater than ever in history. The trends seem to be unique. The Geographical Information System (GIS) was employed to track land use/land cover from 1984 to 2014. Household surveys, in-depth interviews, field observations, and Focus Group Discussions (FGDs) supplemented the information generated by the geographical information system. The data were collected from 104 respondents. Through the geographical information system, six land use classes namely: agriculture with scattered settlements, bush-lands, woodlands, grasslands, plantation forests, and native trees were identified. All land use/land cover classes changed over time. Changes in land use were caused by out-migration, the decline in soil fertility, the absence of a land use plan, and campaigns for planting invasive tree species mainly pines and eucalyptus. The study, thus, recommends the introduction of a land-use plan in each village to enhance natural resource management and reduce conflicting land uses in a specific area.

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KEYWORDS
Land use; land cover; southern highlands; Tanzania; Kipengere ranges

1. Introduction

Land Use/Land Cover (LU/LC) change is not a new phenomenon it existed since time immemorial. However, the current change in land use differs from the previous in terms of its magnitude. The current changes in land use are intensive and have been intensified by increased human demands from the environment (Mligo, 2020). The changes in land use are mainly driven by population growth that puts more pressure on available natural resources. Population growth causes an increase in demand for agricultural land (both for crop production and livestock keeping) and built-up land classes in expenses of other land cover classes (Simon, Lyimo, et al., 2023). Dynamics in land use and land cover are mainly caused by two main factors, namely anthropogenic and natural factors. These factors cause alteration of ecological processes and global loss of biological diversity (Elagouz et al., 2020; Msofe et al., 2019).

The most worrying factors are the human-induced factors because they are very active, and they may bring a substantial change in a short period. Human activities like, the construction of infrastructures, expansion of farmland, and charcoal making just to mention a few play a central role in changing land cover (Elagouz et al., 2020; Mligo, 2020). The human population has some demands from the land, which causes land transformation. Natural resources are mainly used to sustain the livelihood of humankind. For instance, forests are converted to cropland to ensure food security. Human demands from nature trigger the transformation of land use from one class to the other (Molla, 2015). Changes in land use and coverhave in most cases reduced forest cover and pose risks like increased temperatures, erosion, water scarcity, air pollution, and biodiversity loss (Simon, Lyimo, et al., 2023; Simon, Yamungu, et al., 2023).

Land use change is one of the key drivers affecting ecological services such as loss of biodiversity because land use change causes forest degradation and deforestation consequently affecting habitat (Rai et al., 2018). In addition, land use and land cover change may intensify soil degradation which impacts food security (Molla, 2015). The Kipengere ranges face a significant change in land use and cover. Changes in land cover if not well-addressed affect the livelihood of the resources in the biosphere. In this case, the study was carried out to track and establish land use classes in the study area, to find out how land use change affected the biosphere in the Kipengere ranges and to ascertain the influence of

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one land use class on the other land category. The output of this study is expected to have a significant contribution to land-use planning and the management of natural resources.

2. Materials and methods

The data on understanding the paradox of LU/LC was collected in the Kipengere ranges southern highlands of Tanzania. The area for the study was selected purposely because it was dominated by invasive tree species, mainly pines. The dominance of invasive tree species has an impact on the landscape of the study area (Private Forestry Program, 2017; Sanga et al., 2022). Kipengere Mountain ranges are located entirely in the Njombe region in Southwest Tanzania at the northern end of Lake Nyasa. The ranges are covered largely with montane grassland. Near Lake Nyasa, the Kipengere ranges are called the Livingstone ranges. The area is surrounded by two main climatic zones, namely highlands and midlands zone (Manga & Mahenge, 2023). The study area is dominated by forest plantations, mainly pines and eucalyptus. In terms of the land cover classes, grassland, plantation forests, bushland, and agriculture dominated the Kipengere ranges. The study employed a mixed research approach in collecting data to address the problem. The approach was employed to serve the purpose of triangulation. One research method cannot provide valid and reliable information (Almalki, 2016; Creswell, 2014).

In tracking LU/LC change, a Geographical Information System (GIS) was applied to track land use change. Analysis of LU/LC change covered a period of 30 (1984–2014) years. The period of thirty years was convenient for different changes in land use to have taken place. The time (years) was selected based on two main reasons. First, is the influence of liberalization policies that intensified land use in Tanzania. Liberalization policies had some impact on land use/land cover change. Second, the selection of the cited years was based on the availability and quality of LandSat images. Supervised classification was employed to establish land use classes. This method was chosen because it can produce accurate and consistent results that match the expectations and objectives of the user. On top of that, the supervised classification produces excellent results for the larger areas compared to unsupervised and object-based classification (Kafy et al., 2021). To obtain the training sites, samples of different land use cover were collected in the study area. Training sites were collected in the field using a pre-calibrated Global Positioning System and in the lab by downloading high-resolution images from Google Earth through the aid of QGIS v3.16 open-source software.

Two different satellite images were obtained by downloading from the United States Geological Survey geoportal (https://earthexplorer.usgs.gov): Landsat 5 Thematic Mapper (TM) was employed in 1984, 1994, and 2004; Landsat 8 Operation Landsat Imager (OLI) captured spatial data for 2014, all in path/row 169 and 67, respectively, with a spatial resolution of 30 m. The accuracy and kappa coefficient for 1984 data were found to be 86.62% and 0.8273, respectively, while for 2004 data, the accuracy and kappa coefficient were 71.48% and 0.7397, respectively. To establish drivers for LU/LC changes four methods were adopted: Focus Group Discussion (FGDs), in-depth Interviews, field observation and household survey. These methods had some shortcomings. For instance, it was difficult to administer the household survey because it demanded some level of literacy. To solve this problem, the questionnaires were administered by the researcher. On top of that, it was difficult to listen at the same time take notes on what was being said by the interviewee during the in-depth interviews. This problem was tackled by recording the conversation by the tape recorder under the consent of the respondent.

A total of 104 respondents were involved in the study. The Household survey involved 83 heads of households, in-depth interviews involved 6 key informants and FGDs involved 15 respondents. To ensure ethical issues, consent from the respondents and other relevant stakeholders was highly observed during the execution of the data.

3. Research findings and discussion

This section presents the research findings and discussion. Specifically, it presents trends and the land use classes identified through the application of GIS. The section also presents findings on the influence of land use classes on each other. All the presented findings have been supported by the literature related to the present study.

3.1. Trends in land use/land cover change in Kipengere range from 1984 to 2014

To establish trends in land use change, GIS was employed to track LU/LC change in the study area from 1984 to 2014. Through the application of GIS, six land cover classes were identified. The identified land cover classes include agriculture with scattered settlements, bushlands, woodlands, grasslands, plantation forests, and native trees (Table 1). All the identified land use classes experienced changes over time.

Findings presented in Table 1 indicate that in the study area, land use/land cover changed negatively and positively. Positive change implies that LU/LC increased in size and this negatively

Table 1. Land use change in the study area from 1984 to 2014.

	Year and size of land cover							
	Year: 1984		Year: 1994		Year: 2004		Year: 2014	
Land Use/Cover Types	Ha	%	Ha	%	Ha	%	Ha	%
Agriculture with scattered settlements	619	3	907	5	2,206	12	1,815	10
Bushland	7,349	39	4,795	25	2,215	12	1,819	10
Grassland	1,472	8	3,309	18	415	2	636	3
Native trees	964	5	2161	11	1126	6	1036	5
Woodland	8,388	44	7,582	40	6,920	37	12,324	65
Plantation forest	70	0	109	1	264	1	291	2
TOTAL	**18,862**	**100**	**18,863**	**100**	**18,863**	**100**	**18,863**	**100**

Source: Landsat TM (1984 & 2004), Landsat OLI (2014).

impacted other land classes. As one LU/LC class increased in size, the other decreased because such expansion did happen on the expenses of the other land use classes. Likewise, Maitima et al. (2010) found that in the Lake Victoria basin, Tanzania, while the cultivated and grazing land expanded, the other land use classes were intensifying. This impacted the natural ecosystem where the livelihood depended. For instance, the study by Abiye et al. (2023) revealed that land use change caused the decline in soil fertility hence lowering the crop yield in the Maybar watershed, Awash Basin, Ethiopia. In terms of negative change, implies that land cover in a respective land class declined in size. Concerning these findings, one of the participants of FGDs at Ukwama village insisted on the following:

> . . . human demands from nature cause land-use change. Human beings transform nature to establish cropland for food production. The land also is transformed to establish a settlement. Generally, human beings determine the type of land use and land cover change positively or negatively.

The current study further found that some parts of land that were used for food crop production were transformed into tree plantations mainly pines. The pines fall within the genus of pinus. On top of that, pines are among the most invasive plants in the study area. In most parts of the world pines have invaded and colonized the native trees hence changing the land cover (Policelli et al., 2023; Sanga et al., 2022). The impacts of pines result from increased abundance in areas where initially they were absent or less common. The pines are considered invasive because they tend to colonize native trees (Global Invasive Species Database, 2023). The pines are considered invasive species although the International Union of the Conservation of Nature (IUCN) standards are not yet accepting pines to be invasive species. In the Kipengere ranges, pines have invaded and colonized the native trees. In this case, in Kipengere ranges pines are considered invasive species.

Through FGDs, it was found that the decrease in land used for cultivation and settlement was attributed to out-migration and the introduction of invasive trees. People tend to migrate as a survival strategy. One of the key informants insisted: *"Most people planted invasive trees in areas formally used for farming and settlement"*. This explanation is captured in the following Plate 1.

Plate 1. Invasive trees occupied area reserved for settlement.

The whitish/reddish objects on the fore, middle, and rear parts of the plate are houses surrounded by invasive trees, mainly pines.

Findings in Plate 1 reveal that invasive trees were planted in areas reserved for settlements. That is why houses were overcrowded and others were invisible. Plate 1 further is an indication that change in land use caused settlements to be invaded by invasive trees. Likewise, the study by Lusasi et al. (2020) revealed that the timber rush in the southern highlands of Tanzania attracted urban-based investors without local ties, urban-based investors originating in the area in which the investments are taking place, resident villagers, government and religious institutions and local leaders. This caused the intensification of tree plantations in the southern highlands of Tanzania. In the current study, the data from GIS also indicated that in 1984 cultivated land and settlement covered an area of 619 ha out of 18,862 ha of land in the study area. This is equivalent to 3% of the total land available in the area. Even so, ten years later, land for agriculture and scattered settlement changed to 907 ha. In terms of percentages, Table 1 indicates that in 2004 the agriculture and settlement land

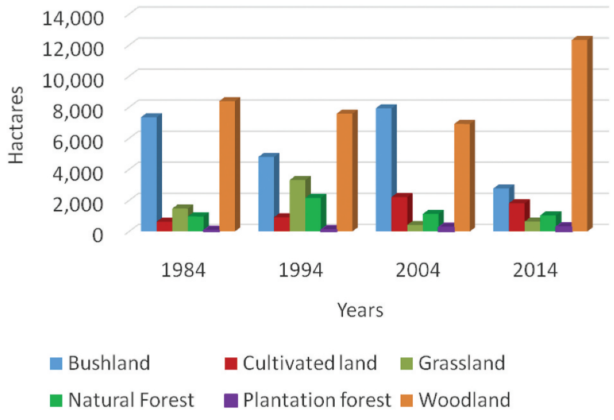

Figure 1. The trend of land cover change from 1984 to 2014. Source: LandSat TM (1984 & 2004), LandSat OLI (2014).

covered 12% out of 100%. This implies that more land was used for farming and settlement. However, in subsequent years land used for farming and settlement was invaded by invasive trees (Figure 1).

Findings presented in Figure 1 indicate that all the land use classes experienced dynamics over time. The dynamics were highly influenced by anthropogenic drivers. In 2014, the researcher discovered that the cultivated land decreased from 2,206 ha to 1,815 ha out of 18,863 ha of the total land. Similar findings were reported by Abiye et al. (2023) in the Maybar watershed, Awash basin, Ethiopia cultivated land and native trees increased significantly over time. However, the study is silent about the cause of the increase in cultivated land and forests. Based on the findings obtained through FGDs, land used for agriculture and scattered settlement experienced positive and negative changes. One of the key informants at Utweve Village claimed that *"dynamics in a population of the study area caused fluctuations in land used for cultivation and settlement"*. In the population and housing census of 2002, the study area had 105,775 people while in the census of 2012, the study area had 97,266 people (The United Republic of Tanzania [URT], 2013). The population increased to 109,160 people in the study area (The United Republic of Tanzania [URT], 2022). This trend of the population from 2002 to 2022 shows fluctuations in the population size. This influenced changes in the land use/land cover in the Kipengere ranges. This is contrary to what was reported by Msofe et al. (2019) who found that in Kilombero Valley, Tanzania, from 1990 to 2016 agricultural land kept increasing over time. This was caused by increasing demands for land for farming activities.

With regards to change in land use and land cover, the findings from the household survey indicate that 99% of respondents revealed that land cover in Kipengere ranges changed significantly. Most of the land uses were new. For instance, in the 1980s few areas had invasive trees; the dominant trees were the natural ones but during the time of conducting this study areas were dominated by plantation forests. Likewise, the study by Taiwo et al. (2023) revealed that developmental processes changed the land cover. New land cover mainly built up and bare land emerged. So, the built-up and bare land became the dominant land cover. This is different from what was found in the current study in which the plantation forests became the dominant land cover. Moreover, only 1% of respondents reported that there was no change in land cover. This category comprised respondents who were not aware of the historical background of their surroundings. LU/LC is dynamic how come in the study area no land use changed from 1984 to 2014? The period of thirty years is long for the area to experience no land use change. However, 99% is enough to conclude that LU/LC in the study area changed over time as depicted in Figure 2.

The current study revealed that native trees experienced changes from 1984 to 2014. For instance, in 1984 native trees covered 964 ha in 1994 they increased to 2161 ha. In 2004, the native trees declined to 1126 ha. This trend indicates that there were fluctuations in the area covered by the native trees. Concerning the decline in the area covered by the native trees one of the participants of FGDs at Ukwama Village revealed that *"some of the native trees were invaded by invasive species while others were cleared in favour of planting invasive trees and establishing farms for food crop production"*. This is in line with the findings of Othow et al. (2017) who found that in the Gog District, Gambella Regional State, Ethiopia, farmland increased, while the native trees declined from 23% in 2002 to 18% in 2017. This implies that farming activities affect the existence of native trees. In some places, such land expanded at the expense of native trees (Plate 2).

Plate 2. Cultivated land with complete removal of native trees.

Plate 2 indicates that trees were cut in favour of establishing cropland. The stumps of trees existing in the cultivated land served as evidence that initially the area was covered by trees. Hence, farming activities threaten native tree species. It will take a long time for cultivated land to regenerate into native trees or woodland. The respondents in FGDs revealed that farmers invaded the

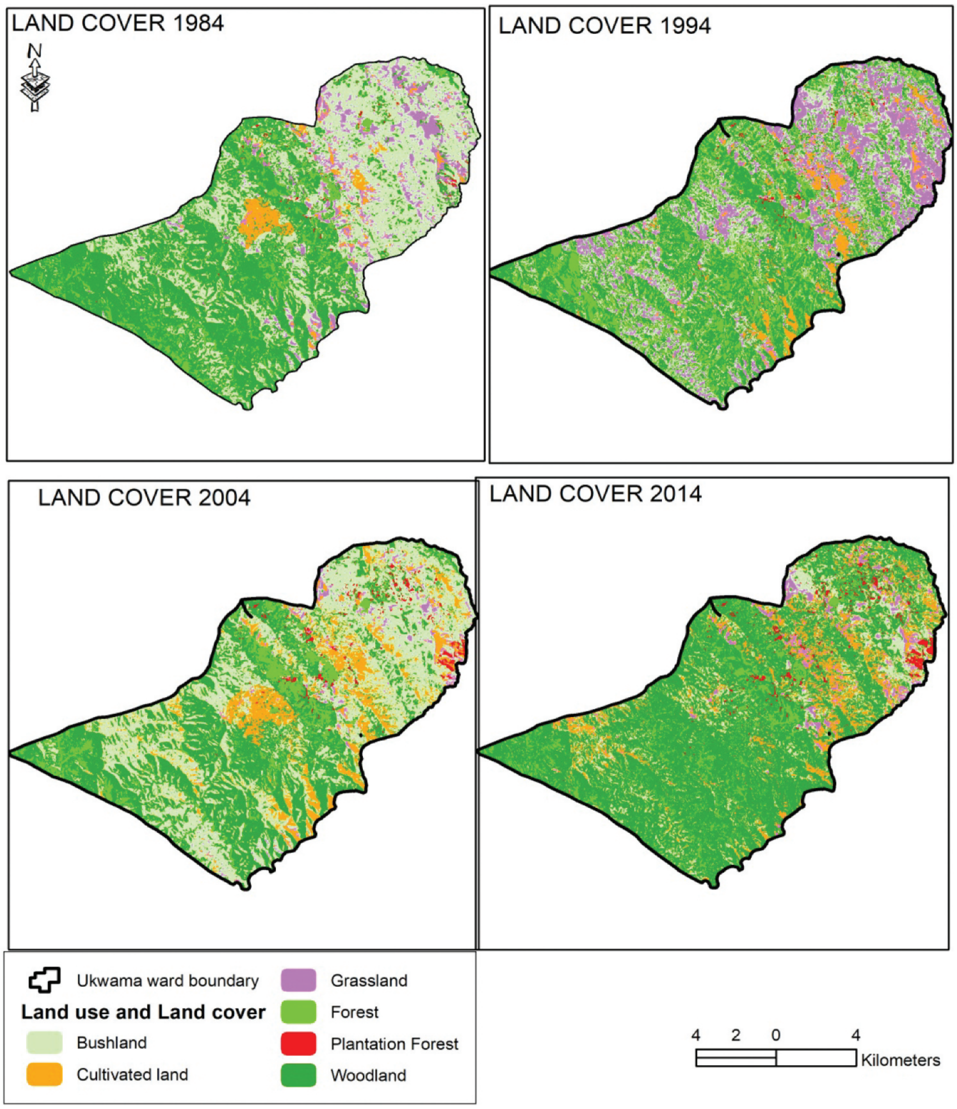

Figure 2. Maps for land cover change in the study area from 1984–2014. Source: Landsat TM (1984 & 2004), Landsat OLI (2014).

native trees due to a shortage of fertile land. The preparation of land for crop production sometimes involves the complete removal of trees found in the given land needed for farming. Through field observation, it was observed that in some places farmers applied selective removal of trees while preparing land for food crop cultivation. This degraded the native trees, hence hampering their capacity to function properly (Plate 3).

Plate 3. Cultivated land with partial removal of trees.

Plate 3 indicates that some of the trees were left during farm preparation. Some of them were cleared. Leaving trees in the cultivated land creates an environment for land use changing to woodland or bushland. This kind of farm preparation is somehow environmentally friendly. Farmers consider the well-being of other living organisms when they prepare the farming site. LU/LC change was also driven by a decline in soil fertility. This affected the area covered by native trees, bushland and woodland. This is evident from GIS results in which the mentioned LU/LC classes declined and increased over time (Table 1). In support of this, one of the key informants at Utweve Village had this to say:

> Famers have developed a culture of abandoning the lands which have lost soil fertility. Land loses soil fertility due to continuous cultivation. After the soil has become infertile is abandoned and farmers invade other land use classes such as native trees, grassland or bushland for establishing farmlands.

Table 2. Land cover change matrix between 1984 and 1994.

	Year: 1984						
The year 1994	Bushland	Cultivated land	Grassland	Native trees	Plantation forest	Woodland	Total year 1994
Bushland	2,650	138	171	204	11	1,694	**4867**
Cultivated land	364	146	313	1	0	89	**914**
Grassland	1,746	254	848	2	15	418	**3283**
Native trees	323	12	7	406	0	1,468	**2216**
Plantation forest	60	2	4	0	45	0	**110**
Woodland	2,216	68	129	358	0	4,703	**7474**
Total in year 1984	**7360**	**619**	**1471**	**971**	**72**	**8373**	**18865**

Source: LandSat TM (1984 & 2004), LandSat OLI (2014).

3.2. Land cover change matrix between 1984 and 1994

The study through GIS analysis indicated that in 1984 cultivated land occupied 619 ha and about 146 ha of cultivated land remained unchanged. The cultivated land in 1984 was small since the area had few people. The cultivated land experienced positive change over time partly due to population increase. Out of 619 ha of cultivated, 138 ha changed to bushlands (Table 2).

3.3. The land cover matrix between 1994 and 2004

In the Ukwama ward, the cultivated land in 1994 comprised 914 ha; the land that remained unchanged comprised 647 ha. About 266 ha of cultivated land changed and became part of other LU/LC classes. About 199 ha of cultivated land changed to bushland, 52 ha changed to woodland, 1 ha changed to plantation forests, and 14 ha changed to grassland. No part of cultivated land changed to a natural forest (Table 3).

Table 3 shows that native trees did not gain from cultivated land. The reason for this could be that farmers cleared all trees as they prepared croplands. This caused a loss of natural trees that later could have formed native trees. In FGDs, one of the key informants at Ukwama Village revealed this assertion by saying:

> It is rare to see a tree standing on cultivated land. Farmers clear all the trees during the preparations of their farms. The trees are cleared because once are left in the cultivated land; they tend to lower the crop yields.

Generally, the findings obtained through the application of GIS revealed that the cultivated land expanded and declined over time and place. Most of the cultivated land which lost soil fertility was abandoned and the other was used for tree plantation. The current study found that only infertile agricultural land was transformed for other land use. This is contrary to the study by Musakwa and Van Niekerk (2013) who observed that in Stellenbosch, South Africa, the highly productive agricultural land was transformed for other land use. Such transformation reflects what Haulle (2015) claimed in his study by documenting that soils that failed to support other food crops could support the growth of Jatropha to improve the income and well-being of the community. For communities engaging in agricultural activities, it was rare to see fertile agricultural land transformed into other uses because farmers needed fertile land for crop production to yield more crops, for commercial and home consumption. Generally, GIS analysis showed that all land classes such as forest, woodland, bushland, grassland, and cultivated land experience gross loss and gross gain.

4. Conclusions and recommendations

The study area experienced significant changes in LU/LC from 1984 to 2014. The identified land use classes (agriculture with scattered settlements, woodlands, grasslands, plantation forests, native trees, and bushlands) changed positively and negatively over time. No land cover class kept increasing over time; all land use classes experienced fluctuations over time. Moreover, overdependence on farming activities as a source of income influenced immensely the land use and land cover change in Kipengere ranges. It is further concluded that the native trees experienced relatively positive changes despite the increased demand for forest products. The positive change was influenced by the role

Table 3. Land use change matrix between 1994 and 2004.

	Year: 1994						
Year 2004	Bushland	Cultivated land	Grassland	Native trees	Plantation forest	Woodland	Total year 2004
Bushland	3,006	199	2,051	393	0	2,291	**7941**
Cultivated land	405	647	729	35	2	377	**2195**
Grassland	27	14	363	2	0	8	**414**
Native trees	136	0	3	362	0	627	**1127**
Plantation Forest	82	1	73	0	109	0	**265**
Woodland	1,210	52	60	1,424	0	4,169	**6915**
Total in year 1994	**4865**	**914**	**3280**	**2216**	**110**	**7473**	**18858**

played by indigenous knowledge in which the native trees were used for traditional functions. The anthropogenic factors were responsible for changes in land use and land cover experienced in the study area. For instance, overutilization of land for crop production caused a decline in soil fertility. This was the case because farmers used the same piece of land without the application of the following. The land which lost soil fertility was abandoned from farming activities due to the inability to revitalise the soil. High prices of inorganic fertilizers caused farmers to abandon infertile soil and clear native trees to establish farms for food crops. Moreover, the expansion of a given land use class occurred at the expense of the other land use type. The absence of a land use plan also caused land use change in the study area.

It is recommended that all study villages must introduce a village land use plan. The plan has to indicate different uses of land such as land for settlement, land for farming activities and other related uses. There is a need to introduce other income-generating activities. This will reduce over-dependence on farming activities as a source of livelihood. For instance, they may establish beekeeping as a source of income. There is also a need for the government to impose subsidies on inorganic fertilizers. This will enable more farmers to access fertilizer and hence reduce the invasion of native forests for establishing farms. It is also important to create a conducive environment for the operation of traditional functions because they facilitate forest conservation. Finally, the study recommends that there is a need to educate farmers on the use of manure as an alternative way of revitalising soil that lost its fertility. This will help to reduce the abandonment of the land that has lost soil fertility.

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