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Research Article

Monitoring Forest Cover Change in Kalomo Hills Local Forest Using Remote Sensing and GIS: 1984-2018

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ABSTRACT

The purpose of the study was to use remote sensing and GIS to assess forest cover change in Kalomo hills local forest. It sought to determine land cover change, quantify forest cover change, and identify the drivers of forest cover change over this period. This was a case study which employed mixed methods. Primary data and secondary data sources were used. Landsat satellite imagery of the study area were used. Image processing, classification and analysis of remote sensing satellite imagery data was conducted using Arc GIS 10.3 to produce change maps, and land cover change statistics. The study employed supervised image classification using the maximum-likelihood classifier algorithm on Landsat images for 1984, 2004, and 2018. Change detection was performed using the post-classification comparison from which change matrices were generated. Thematic analysis was performed in Statistical Package for Social Scientists version 22 and Microsoft Excel 2013. Land cover change during the period under study was mainly from forest to cropland and grassland. The forest reserve covers 162, 200 hectares. It lost about 82, 975 hectares of forest since 1984 at an average rate of approximately 2, 514 hectares per year, equivalent to 2 percent per annum, leaving only 24.2 percent of the original forest unchanged. By 2018 forest cover as a percentage of the total forest reserve area was approximately 23.1 percent. The main proximate driver of forest cover change in Kalomo hills local forest was found to be agricultural expansion for cropland. The others were wood extraction and infrastructure extension. The main underlying driver of forest cover change was found to be population growth. The findings provide a basis for appropriate policy intervention to ensure sustainable utilisation of the forest and forest resources.

Keywords: Forest; Geographic information system; Land use; Land cover; Remote sensing

INTRODUCTION

There is growing concern globally over land cover and land use change due to unsustainable utilisation of forests. Forests play an important role in the global ecosystem by providing several environmental services such as stabilising soils and climate, and regulating water flows [1]. The ability of the ecosystem to continue providing these services and products as well as supporting biodiversity is under threat from land use and land cover change. Cases of forest degradation and deforestation have been reported across the globe. Forests in Africa are suffering from deforestation or degradation, which is not only affecting ecosystems but also the means of life for local populations and women in particular. The loss of forests have also impacted on humanity as a whole through global climate change and loss of biodiversity [2].

Remote sensing and geographic information system are valuable tools for studying land use and land cover change. Remote sensing provides imagery with spatial and temporal resolution, and efficient technology that can enhance our understanding of forest change. A GIS enables data capture, storage, manipulation and output, and has the ability to integrate raster, vector, and tabular data structures of varying scales thereby making it very useful in land use and land cover change analysis. Remote sensing data have become the major data sources for change detection applications with advantages of repetitive acquisition, its synoptic view, and digital format suitable for computer processing [3]. Change detection is the process of identifying

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differences in the state of an object or phenomenon by observing it at different times. Repetitive acquisition of multispectral satellite imagery using remote sensing makes change detection possible between any two points in time. This is also enhanced by the availability of multispectral and hyperspectral imagery that enables identification of earth surface features. Using these tools, delineation of land cover and land use types and quantifying changes in forest condition is possible and can contribute to forest protection and management. Remote sensing provide coverage at varying scales from local to global, and at various spatial and temporal resolution [4].

The Global Forest Resource Assessment (FRA) report indicates that the world's forest area cover declined from 31.6 percent of the global land area to 30.6 percent between 1990 and 2015. This indicates a continued decline in forest cover over two and half decades. For the period 1981 to 1985, the net forest loss per year was 10.2 million hectares in tropical developing countries and 11.4 million hectares global net forest loss per year. This implies the greater loss of forests per year took place in tropical developing countries. Between 1990 and 2000, global forest area reduced by around 7.3 million hectares per year (0.2%) and by around 4 million hectares per year (0.1%) per year between 2000 and 2010. The food and agriculture organisation further says that between 2010 and 2015 the area of forest reduced by 3.3 million hectares per year, a rate of 0.1 percent per year. In some decades there was decrease in net forest area loss and this was mainly attributed to forest planting, landscape restoration, and natural expansion of forests. Globally the largest proportion of forest was converted to cropland. The millennium ecosystem assessment reports that over the last 300 years agriculture was created at the expense of natural forests, grassland and wetlands that provide valuable habitats for species and valuable services for humankind [5].

The Southern province's forest cover as a proportion of the total provincial land area is 54.95 percent and has about 8.18 percent of the country's forest area. The province originally had 33 forest reserves but currently only has 30 as the other three have been de-gazetted to pave way for other land uses. All of these 30 forest reserves have management plans from the 1960s, most are heavily encroached and degraded. The vegetation of Kalomo district is characterised mainly by open forest comprising a combination of Miombo, Mopane, and Munga woodlands, and grassland. Kalomo hills local forest reserve has similar vegetation characteristics to parts of the district but literature on micro-level characteristics is sparse [6].

Kalomo hills local forest, in southern province, lacks up-to-date data on its state, has been encroached and settlements have been established therein. Quantitative data on drivers, rates and areal extent of forest cover change for the forest is lacking. This situation hampers strategic decision making and timely intervention. The Forest Department has previously solely depended on in-situ methods of collecting data in the forest. These methods have proved to be costly, time-consuming, labour intensive and cumbersome. Against such a background it was important to study how the forest has changed over time. There are studies that applied remote sensing and GIS in forest cover mapping in Zambia. Large nationwide projects such as Zambia National Forest Monitoring System (NFMS), which were designed to capture data for global forest inventory reporting also applied the capabilities of geospatial technologies. These inventories were not specific to different forest ecosystems and structures found across the country. As such these projects did not clearly or comprehensively provide quantitative information on the status of individual forest reserves in Zambia hence the need to undertake a localised and detailed study [7]. Availability of such information is vital at both local and national levels to provide guidance or regulations against inappropriate use of forest resources. Therefore, this study applied remote sensing and geographical information systems technologies to assess forest cover change in Kalomo hills local forest number P13 over a 34-year period. It sought to determine land cover change, quantify forest cover change, and identify drivers of the forest cover change in Kalomo hills local forest from 1984 to 2018. Using remote sensing in combination with GIS, it is possible to efficiently map deforestation, quantify forest loss, determine the rate of forest change and produce change maps. These tools provide timely alternative to in-situ methods. Geospatial technologies are for efficient, accurate, timely provision of information on forests without which deforestation and forest degradation and the negative impacts would go unnoticed and unabated.

STUDY AREA

Kalomo hills local forest number P13 is located approximately 40 kilometres north of Kalomo town. It lies in Kalomo and Kazungula districts of southern province in Zambia between 26° E and 27° E, and 16° S and 17° S. The forest covers an area of 162, 200 hectares. The Forest Act of 1973 provide guidelines on the purpose of Local Forests, that they shall be used exclusively for the conservation and development of forests with a view of securing supplies of timber and affording protection to land and water resources in the local area. The soils in Kalomo district, classified as plateau soils, range through clay and clay sandy mixture. The sandy soils have heavier textured subsoils, leached with low inherent fertility. They are described as being generally poor soils for crop cultivation because they have low nutrient reserves and poor moisture-retention capacity [8]. These are the soils that also occur in Kalomo hills local forest and also alkaline dark-grey clays that are seasonally waterlogged. Kalomo district experiences a humid subtropical climate, classified as warm temperate, winter dry, and extremely continental. The average temperature is 19.9 degrees celsius. Annual rainfall amount ranges from 800 mm to 1000 mm per annum. Kalomo hills local forest has the same climate as that of Kalomo district.

The highest density of vegetation occurred near hills and in riparian zones. Grassland occurs mostly in low lying areas of the forest, near streams, and on abandoned crop fields. These low lying areas experience inundation during some parts of the rainy season and are generally covered by grass during most parts of the year. The highest density of grassland occurs on the western, eastern and southern boundaries of the local forest reserve. During this period the annual population growth rate for Kalomo was 5.4 percent, which was above the national average rate of 3.0 percent. The proportion of rural population in

Kalomo was 93 percent, most of whom were female at 51.3 percent. The study area is dominated by Tonga speaking people, some born within the district and others migrants from other districts of southern province. Part of this group were the internally displaced valley Tonga from the Zambezi valley due to the construction of lake Kariba. In 1984 there were just over 10 villages in Kalomo hills local forest. The population has continued to grow over the period under study. This growth has been attributed to natural increase and in-migration. In 2018 there were over 50 villages within Kalomo hills local forest with an estimated population of more than 57, 000 people [9].

Kalomo hills local forest is dominated by small-holder agricultural activities. Maize cultivation is the major economic activity of the people. Other crops grown include sunflower, groundnuts, cotton, sweet potatoes, beans, cow peas, soya beans, and tobacco. Growing of sweet potatoes and vegetable gardening is growing in prominence as a way of crop diversification. Gardening activities are commonly conducted along river and stream banks and in irrigation schemes. Livestock is mainly restricted to cattle, sheep and goat rearing. Outbreaks of trypanosomiasis due to tsetse flies in the mid-1980s led to reduction in cattle population in the area as well as migration by a number of families away from the local forest reserve. This had a negative impact on economies at family level in that these families lost cattle and could not cultivate crops on their farm plots. Nevertheless, tsetse control operations and cattle restocking by government have led to an increase in the number of cattle as well as area under cultivation [10].

At the time of the study there were very few alternative livelihood activities outside small-holder agriculture and this has been exacerbated by overharvesting of forest resources over the past decades. The expansion of agricultural fields and settlements led to depletion of edible wild fruit trees, tubers, leafy vegetables which apart from providing food provided a source of household income during some parts of the year, especially the growing season when the staple food was in short supply. The munkoyo tuber used to make a traditional drink had been depleted in most parts of the forest due to overharvesting and expansion of cropland. Exploitable trees for construction material and for wood fuel were also in short supply due to deforestation and forest degradation [11]. The Zambia forestry department, with the headquarters in Lusaka, is in charge of the management and protection of forests in Zambia. Kalomo hills local forest is under the management of Kalomo district forestry office and the southern province forestry office in Choma district. Restrictions in local forests include squatting, camping, residing, building or excavating, or constructing or using any enclosure, or constructing or reopening or using any road other than a public road, or erecting or operating any plant, machinery of equipment, graze domestic animals or allow domestic animals to trespass, clearing, cultivating or breaking up land for cultivation or other purposes, or grow crops.

MATERIALS AND METHODS

The research design used in this study is a case study. This study combined household survey and remote sensing approaches. The research used a mixed method approach, which employed both qualitative and quantitative techniques in order to come up with the results. Qualitative methods were used to analyse data in order to identify the drivers of forest cover change. Quantitative methods were used for classifying the images into land cover classes, sampling training sites for classification, and test pixels for accuracy assessment. Quantitative methods were also used to determine land cover change, and for calculating the rate of land cover change between the time periods using remote sensing and geographic information systems. The sample for respondents was drawn from residents that have been living in the forest reserve for more than 24 years. Respondents were chosen from within areas with evidence of encroachment, and deforestation. These areas were identified from satellite imagery in ArcGIS 10.3 before field work was undertaken. The sample size for this study was forty. The study involved thirteen key informants. These were ten senior headmen and three public office bearers. One officer from Kalomo district forestry office, one officer from Kalomo town council and one officers from Kalomo district agriculture coordinator's office who were interviewed. The officer from the ministry of agriculture provided information concerning agricultural activities taking place in the study area and government policies influencing agriculture in the district. The officer from the forest department provided information on forest management in the district and policies influencing it. The officer from the town council provided information concerning settlement and livelihood in the study area [12].

Non-probability sampling was used to select respondents and key informants. Snowball sampling was used to select household heads that had been living in the area since at least 1994. The sampling of test pixels for accuracy assessment of image classification was done by use of stratified random sampling. Primary data sources were interviews, ground surveys using GPS, field photographs, field observations through transect walks. Structured interviews were conducted with heads of households that had been living in the forest reserve for at least 24 years in order to obtain information about the drivers of forest cover change. Semi-structured interviews were conducted with key informants in order to obtain information on drivers of forest cover change, and the historical perspectives on factors that influenced this change. Field observation was used to obtain data on people's economic activities, occurrence of certain vegetation types and infrastructure in the forest reserve. Photographs taken during field visits were used to validate what was observed in the field. The GPS was used to mark the location of areas of land use and land cover for use as training sites during the classification process. Other training sites were collected using google earth.

Secondary data sources were archival data and Landsat satellite imagery. The multi-date images required for the study were obtained from various sensors. Several studies have used Landsat imagery for their studies. The downloaded images were georeferenced to the coordinate system WGS 1984, UTM Zone 35S. Thematic analysis was conducted using Statistical Package Social Sciences version 22 and Microsoft excel 2013 in which descriptive statistics were generated and presented in tables and as graphs. Thematic analysis was used to analyse data on drivers of forest cover change. The respondents were also asked about the land cover that has replaced forest cover. This was cross-validated using classified images and statistics generated from image analysis. Image classification was conducted in ArcGIS 10.3 using supervised classification by creating training sites based on familiarity with the study area using the maximum likelihood classifier. Training samples for the land cover classes were created from the colour infrared imagery. These training samples were well distributed across the image to ensure good representation of all classes in the scene. Training samples were created based on land use and land cover classes and then signature files were generated. Signature files were then used to come up with a land cover classes for the whole image based on spectral signatures from the areas of interest.

RESULTS AND DISCUSSION

Accuracy assessment results of the image classification for 1984 had a kappa coefficient and overall accuracy of 0.92 and 94 percent respectively (Table 1). For 2004 the kappa coefficient and overall accuracy were 0.89 and 92 percent respectively. The image classification for 2018 had kappa coefficient and overall accuracy of 0.87 and 90 percent respectively. The use of medium, 30 metre, spatial resolution Landsat imagery for image classification meant that the occurrence of mixed pixels was eminent as such the accuracy of the classification could not be perfect. For example, the classification for the 1984 satellite image has producer's and user's accuracy of 92 and 88 percent respectively. This means that 92 percent of forest area has been correctly identified as forest but that only 88 percent of areas identified as forest in the classification are truly of forest category.

Classification data	Reference points			
	Water	Cropland	Forest	Grassland
Water	36	0	0	0
Cropland	0	39	0	0
Forest	3	0	37	2
Grassland	1	1	3	38
Column Total	40	40	40	40

Table 1: Error matrix for 1984.

Its total area declined from 1984. From 1984 to 2004 cropland and grassland increased by 289. 0 and 63.3 percent respectively, water and forest cover decreased by 76.9 and 41.7 percent respectively. The change from forest to other land uses and land cover was attributed to many factors. The increase in area under grassland can be attributed to the regeneration of grass in crop fields which had been previously abandoned due to tsetse fly outbreaks in the early and mid-1980s. According to some key informants many people lost their livestock due to tsetse fly infestations and so they left the forest reserve to live in other parts of the chiefdoms as such were not able to cultivate their crop fields for several years. The average rate of forest cover change over this period, was approximately 2,514 hectares per the annum. This translates into a rate of about 2.1 percent per annum. From covering about 120,343 hectares in 1984, forest to cover was about 70,164 hectares in 2004. The forest reserve losts approximately 50,180 hectares of forest cover over this period, a decrease of 41.7 percent. The change in forest cover over this period was mainly be attributed to population increase, and the consummate rise in the area under cropland.

The average rate of forest cover change for this period, was approximately 2,336 hectares per annum. This translates into a rate of 3.3 percent per annum. From covering about 70,164 per hectares in 2004, forest cover was about 37,459 hectares into the 2018. The forest reserve lost approximately 32704 hectares of the forest cover over this period, a decrease of 46.6 percent. The increase in population, inadequate monitoring by the forest department, decreasing soil productivity, lack of management plans, unsustainable utilisation of forests, and other factors may have acted together to increase the area under cultivation at the expense of forest. The average rate of forest cover change in Kalomo hills local forest over the thirty-four year period under study was 2,440 hectares per annum. This translates into a rate of of 2 percent per annum. From covering about 120,343 hectares in 1984, forest cover in Kalomo hills local forest reserve was about 37,459 hectares in 2018. The forest reserve lost rate forest approximately 82,884 hectares of forest cover over this period, a decrease of 68.9 percent.

Agriculture expansion

The key informants stated that there were over 12,700 farmers to within Kalomo hills local forest in 2018. The study revealed that agriculture expansion was due to opening up of the forest in order for farmers to create farm plots on which to grow crops. Agricultural expansion was a result of the need satisfy the household income through sale of produce. The study found that the main crop grown was maize, which is the major food crop (Table 2). Other crops were tobacco and soya beans. The findings of this study are similar to those by Geist and Lambin who identified agriculture expansion as a leading driver of deforestation in tropical countries.

Crop	Frequencies	
	No. of respondents	Percentage (%)
Maize	40	26.7
Sunflower	35	23.3
Groundnuts	27	18
Cotton	15	10
Beans	19	12.7
Sweet potatoes	8	5.3

Table 2: Crops grown in Kalomo hills local forest.

The study found that 92 percent of the population depended on crop cultivation as a source of livelihood expansion of forests of The study found that wood extraction was a driver of forest cover change. This was supported by some key informants who stated that wood extraction, especially for use as pole wood for constructing houses, storage sheds and other farm structure.

The study found that 92 percent of the population depended on crop cultivation as a source of livelihood. The expansion of agriculture is driven by the clearing of forests which entitles the clearer perpetual right to the use the cleared area which in turn increases the land holding of a household. As a consequence, with the majority depending on crop cultivation, there has been increased demand for agricultural land and increased forest clearing in Kalomo hills local forest. They found that the majority of Zambians practice agriculture for food and cash requirements thereby leading to loss of forest resources in many parts of the country. Similarly, in the analysis of drivers and underlying causes of forest cover change in various forest types in Kenya, the Government of Kenya (GOK) identified the expansion of commercial and subsistence agriculture as drivers of forest cover loss. According to the central statistical office, agriculture is the main source of livelihood and highest employer of the rural population in southern province in Zambia. The growing of tobacco by farmers within Kalomo hills local forest was found to have contributed to forest cover change. According to the key informants, the main variety is the fire-cured Virginia tobacco which fetches a higher market price than the sun-dried burley variety. They stated that tobacco is produced under out-grower schemes linked to Tobacco Board of Zambia and other tobacco companies like Tombwe processing. The production of Virginia tobacco contributes to deforestation in Kalomo hills local forest in two ways: firstly, through clearing of forest land to grow it, and secondly, because firewood is harvested for use in curing it.

Infrastructure extension

The study revealed that infrastructure development contributed to loss of forest cover in Kalomo hills local forest for the period under study. Infrastructure development contributed to forest cover loss mainly through land clearing to build various structures Table 3. The study found that since the early 1960s, there had been development of infrastructure within Kalomo hills local forest but with increasing population this infrastructure had to be improved. The extension of this infrastructure was necessitated by the need for social services as the population increased. The study revealed that infrastructure extension contributed to forest cover change in Kalomo hills local forest in three ways. Firstly through land clearing to pave way for buildings. Secondly, this infrastructure attracted more human settlements that also require clearing of land for construction of housing units. With increasing settlements there was increased pressure on the forest as these people also needed agricultural land for cultivation of crops. Thirdly, some of this infrastructure was been set up by the community in collaboration with governmental and non-governmental organisations that required communities to provide upfront construction materials. The community mostly provided gravel, crushed stones, water and baked bricks. Moulding of clay bricks require huge amounts of firewood as such large tracts of land were cleared in order to provide the firewood needed to fire the brick kilns.

Type of infrastructure	Number of infrastructure
Schools	20
Health centres	5
Telecommunication towers	2
Dams and Irrigation schemes	2
Crop Storage Sheds	3
Maize depots	2
Government camp officers' houses	3

Table 3: Infrastructure found within Kalomo hills local forest.

Wood extraction

The study found that wood extraction was a driver of forest cover change. This was supported by some key informants who stated that wood extraction, especially for use as pole wood for constructing houses, storage sheds and other farm structures as well as for fuelwood by individuals led to deforestation of large tracts of land in the forest reserve. In Kalomo Hills Local Forest the study found that there are no commercial logging activities but there is high dependency on firewood as a source of energy. According to, about 2.4 billion people make use of other farm of wood to provide basic service such as cooking, boiling water and heating. The study found that firewood was the main source of energy for the majority of the people in Kalomo Hills Local Forest. This finding is similar to that by who people make others found that fuelwood was estimated to account for the majority of the Zambian economy's total energy household balance.
Similarly, found that storage led to the farm of people make use that in Africa the harvesting of fuel wood and poles by individuals for domestic uses dominates cases of deforestation associated with wood extraction. Also in their study of land use and land cover mapping using remote sensing and GIS in Aluk Taluk, India, found that forest cover change to the forest economy was as a result of illicit cutting of trees for firewood, charcoal, and making of agricultural implements.

Underlying drivers

Several underlying drivers of forest cover change in Kalomo hills local forest were identified during the study. Other underlying drivers included, inadequate monitoring by the forestry department, lack of regional and catchment management plans, unsustainable utilization of forests, infrastructure development programmes, lack of coordination among institutions, and people's attitudes, values and beliefs towards forests.

Population growth: The study revealed that forest cover change was also a result of the increase in the number of people living within the forest reserve over time. The study found that in the early 1980s there were just slightly above ten villages in Kalomo hills local forest but about 60 by 2018. The increase in population increased the demand for land for settlement, agriculture, and the demand for fuelwood and pole wood. This finding is similar to that by who found that population growth increases the demand for agricultural land, fuel wood, poles and timber.

Resettlement: The study found that in some parts of the forest was an area of resettlement. It revealed that the number of people resettled from the Zambezi valley has increased and as such areas cleared of forest increased. The majority of the people at Nkandanzovu, within Kalomo hills local forest, were internally displaced from the Zambezi valley after the construction of the Kariba dam flooded parts of the valley. As the population increased the demand for land increased as such forests were cleared to pave way for the establishment of settlements and consequently crop fields. They found that resettlement programs drove the conversion of woodland into cropland.

Decreasing productivity: The study revealed that the soils had lost fertility as compared to the early years of cropping. The situation was exacerbated by low fertility of the soils in the forest reserve. The use of synthetic fertilisers had been on the increase because soils could no longer support productive cropping without fertilisers. As a result extending, and opening up of new fields in the forest was done in order to improve productivity. The key informants explained that decreasing productivity from crop fields due to conventional tillage, over-cropping, mono-cropping, and historical overuse of synthetic fertiliser led to agriculture extensification.

Infrastructure development programmes: The study identified several infrastructure that exists within the forest reserve. Nkandanzovu basic school was established by the community but upgraded by the Gwembe Tonga development project which also constructed Nkandanzovu rural health centre. Other programmes included the construction of Nazhila baisc school, Nabusanga basic school, Bilili secondary school, Nazibbula basic school, Nameto rural health centre, and telecommunication towers among other. The construction of these schools led to clearing large areas of land within the forest reserve on which to buildings were to be sited as well as were trees were cut down for use in brick-making kilns as the community provided upfront materials. Some workers deployed in these institutions acquired and cleared large pieces of land on which they grow crops.

Inadequate monitoring by the forest department: The study revealed that the Forest Department officials had not been visiting the area to monitor forest activities. The Forest Department among other reasons has inadequate financial resources, inadequate manpower, and inadequate equipment. This finding is consistent with the 2017 auditor general's report on sustainable forest management in Zambia which states that due to inadequate funding, staffing and lack of transport the forest department had failed to undertake effective monitoring and control activities. This was also supported by who state that the forest department was inadequately staffed with 390 out of 544 positions yet to be filled then. According to mackenzie since 1997 there have been no forest guards in Zambian forest reserves so the supervision of forest operations and general forest regulations enforcement was left up to professional staff at the district forestry offices. The absence of forest guards as such may have exacerbated encroachment and deforestation in most parts of the forest.

Lack of regional and catchment management plans: The lack of regional and catchment management plans was one of the underlying drivers of forest cover change. Key informants explained that the lack of these plans meant unsustainable land use practices persisted perpetually. Regional and catchment management plans explicitly state the land capability and whether the soils were suitable for particular agriculture activities. They stated that these plans provide guidelines on good land management practices and that in the absence of such plans, land use was governed by personal decisions which considerably did not apply expert knowledge of sustainable land use planning and zoning. This led to settlers to indiscriminate clearing of parts of the forest in order to create farm plots for crop cultivation.

Unsustainable utilisation of forests: Unsustainable utilisation of forests through indiscriminate cutting of trees for charcoal production was evident in Kalomo hills local forest. Several charcoal kilns were seen in parts of the forest reserve. The study found that charcoal production was a relatively new phenomenon but was growing in prominence. A charcoal market was established at Nabulangu market but later closed down. Unsustainable utilisation of forests such as for charcoal production contributed to forest cover losses. The finding is similar to that found that charcoal production was the most frequent driver in nearly all the seven provinces sampled for their study, and that the demand for charcoal continued to rise.

CONCLUSION

Land cover change in Kalomo hills local forest during the period under study was mainly from forest to cropland and grassland. The average rate of forest cover change for the period 1984 to 2018 was about 2 percent per annum. The drivers of forest cover change in Kalomo hills local forest are agriculture expansion for cropland, wood extraction for pole wood and wood fuel, and infrastructure development. The cultivation of maize is the leading driver of forest cover change. The establishment of infrastructure which includes settlements, rural health centres and schools contributed to forest loss. Some of the underlying drivers of forest cover change were population growth, inadequate monitoring by the forest department, dependency on wood fuel, resettlement, infrastructure development programmes, lack of regional and catchment management plans, unsustainable utilisation of forests, agricultural subsidies, lack of coordination among institutions, and decreasing productivity. Population growth was found to be the major underlying driver of forest cover change. It influenced the increase in area of land cleared for infrastructure development and extension, for cultivation, and the demand for pole wood and wood fuel.

The forests through indiscriminate cutting of trees for charcoals production was evident in Kalomo hills local forest. Several charcoal kilns were seen in parts of the forest reserve. The study found that charcoal production.

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