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Nanjiva Nzunda
PKT Munishi
Japhet Kashaigili
Geofrey Soka
Joel Monjare

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Land use and vegetation cover dynamics in and around Kagoma Forest Reserve in Tanzania

Nanjiva G. Nzunda[1]*, Pantaleo K. T. Munishi[1], Japhet J. Kashaigili[2], Geofrey E. Soka[3] and Joel F. Monjare[4]

[1]Department of Forest Biology, Sokoine University of Agriculture, P.O. Box 3000, Morogoro, Tanzania.
[2]Department of Forest Mensuration and Management, Sokoine University of Agriculture, P.O. Box 3013, Chuo Kikuu, Morogoro, Tanzania.
[3]Department of Wildlife Management, Sokoine University of Agriculture, P.O. Box 3073, Morogoro, Tanzania.
[4]Geo-Network Limited, P.O. Box 38037, Dar es Salaam, Tanzania.

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Kagoma Forest Reserve (KFR) is found in Kagera Region, Tanzania and is comprised of a large area of Miombo woodland. The extent of land use and vegetation cover changes in and around Kagoma Forest Reserve was investigated. Remote sensing and GIS techniques were used to analyze land use and vegetation cover changes over the past 23 years which revealed the occurrence of significant land use and vegetation cover transformation from one land use class to another. During the first period of 12 years under observations (1988-1999), woodlands increased by 5.8%, cultivated lands increased by 5.9%, settlements increased by 0.52% and forests decreased by 5.64%. During the next 11 years period under observations (1999-2010), woodlands decreased by 22.97%, cultivated lands increased by 6.07%, settlements increased by 9.14% when year 1999 was used as a common baseline data year for both periods and forests which decreased by 2.5%. There was a slight increase in settlements from 1998 to 1999 but there was a rapid increase thereafter. It was estimated that vegetation cover was decreasing at the rate of 45.08 ha (0.27%) per year. The study concludes that, there have been significant changes in land use pattern and forest cover in and around KFR in Tanzania which require concerted actions to reverse the changes. The establishment and enforcement of different laws and regulations relating to natural resources and land use planning could improve land tenure and resource use in villages bordering the forest.

Key words: Land use, vegetation, cover change, Kagoma, Tanzania.

INTRODUCTION

The land use planning for sustainable future requires investigations into possible land use changes and the impact it has on ecological functions and processes at the local level (Zebisch et al., 2004). Land use change is a major driver of habitat modification and can have important implications for entire ecological systems (Lambin et al., 2004). One of the most important land use changes is that the world's forests, grasslands and woodlands have declined, while the cropped land areas have expanded by a similar magnitude (Slayback, 2003). Tanzania's ecosystems have been vulnerable to human driving forces like the land demand for agriculture, pasture, logging,

*Corresponding author. E-mail: nanjivan@gmail.com. Tel: +255 784353051. Fax: +255 232604648.

charcoal making and mining (Ogungo and Njuguna, 2004). Forest and woodland ecosystems in Tanzania occupy more than 45% of the land area, more than two thirds of which is made up of the Miombo wood-land (Nduwamungu, 2001). The main form of land use in the Miombo region has long been shifting and small-scale sedentary cultivation (Walker, 2004).

Studies have demonstrated that expansion of cultivation in many parts of the world has changed land to more agro-ecosystems and natural vegetation (Lyaruu, 2002; Tiffen, 2003). These changes are fuelled by a growing demand for agricultural products important for improving food security and income (Maitima et al., 2004a). For example, in developing world, humans have increased agricultural outputs mainly by bringing more land into production (Lambin et al., 2003). Indeed, land conversion to agriculture in East Africa has outpaced the proportional human population growth in recent decades (Reid et al., 2004). Natural vegetation cover has given way not only to cropland but also to native or artificial pastures (Lambin et al., 2003). Additionally, of considerable importance to land use change in East Africa, is the expansion of urban centres. Olson et al. (2004) reported that in the last few decades, the area under cultivation has more than doubled in Kenya and Tanzania, but in Uganda the change has been moderate due to the enhancement of land policy protecting large parts of Uganda as wetlands. In Kenya, Olson et al. (2004) reported that cultivation expanded by 70% between 1958 and 2001, leaving only isolated pockets of forest and bush. Similarly, in Tanzania, Misana et al. (2003) reported a significant expansion of cultivation in Moshi area over the same period. For example, land scarcity in the highlands made farmers to intensify their land use (increased inputs per hectare) because there was little land available for extension of their farms (Ngailo et al., 2001).

The concerns about land use and land cover change emerged globally due to realization that changes of the land surface influence climate and impacts on ecosystem goods and services (Lambin et al., 2003). The impacts that have been of primary concern, are the negative effects of land use change on biological diversity, soil degradation and the ability of biological systems to support human needs (Kaihura and Stocking, 2003). Crop yields have declined, forcing people to cultivate more land to meet their needs (Kaihura and Stocking, 2003). Grazing areas have become less productive as a result of over-stocking of livestock. Conflicts over the use of land have, therefore, increased due to increased demand for land by different sectors of the economy. One of the particular concerns is the conflicts among cultivators, livestock keepers, wildlife conservationists, individual land users and governments due to encroachment of humans into the protected areas (Hoare, 1999; Campbell et al., 2003).

Anthropogenic alterations of the natural landscape through urbanization, agriculture and forestry have been a continuous and increasing process for the past millennium (Vanacker, 2002). Areas of the natural vegetation and land cover are removed and replaced with the human managed systems of altered structure (Lundgren, 1978). During the last century, land use has changed drastically in the tropics due to a changing economy and growing population (Meyer and Turner, 1992). This has caused significant and adverse effects on physical and ecological process (Briassoulis, 2002), on soil and water (Munishi et al., 2006) on local and global climate (Turner et al., 1994) and on biodiversity (Association of American Geographers, 1996). Studies by Meyer and Turner (1996) showed that land use deliberately alters land cover such as vegetation by changing it into a different state such as building materials, medicinal, wood and fuel, hence deforestation. Recently, efforts have been made to quantify the nature and extent of land use/land cover changes including vegetation at global scale (Zhou et al., 2008; Kashaigili, 2008; Dewan and Yamaguchi, 2009). Richards (1990) estimated that, over the last 300 years, the total global area of forest and woodland diminished by 19%, while grasslands increased by 46.6%. Despite the recognition of the magnitude and impact of global changes in land use and land cover, there have been relatively few comprehensive studies on land use changes and their impacts (Strategic Plan for the climatic change Science programme, 2003). Kaoneka (1993) reported on the analysis of land use changes based on sequential aerial photographs in the Usambara Mountains, Tanzania. The report revealed a declining area of natural forest reserve at a fairly high rate of 3.8% per year at the expense of farmlands and settlements which increased dramatically by 83% per year. It also reported that this change was mainly due to population increase which resulted in more pressure on land and forest resources. Misana et al. (2003) on the other hand reported a significant expansion of cultivation in the Kilimanjaro region, as well as other north-western regions. Like many other developing countries, most of the population in Tanzania live in rural areas and depends directly on the land for their livelihoods (Kashaigili and Majaliwa, 2010). This rural population is causing resource degradation brought about by the decrease in the area under natural vegetation and its conversion into other types of land use and land cover that are human-managed systems (Kashaigili and Majaliwa, 2010).

Misana et al. (2003) found that the increased population as a result of the influx of refugees, including an increase in the local population, have had an impact on forest resources in north-western Tanzania. However, no quantifications have been done to establish the magnitude and pattern of land use and vegetation cover changes in and around KFR. This study, therefore, assessed the extent of land use and vegetation cover changes in and around KFR. Specifically, the study investigated long-term changes that have occurred as a result of human activities in the area for the periods between 1988

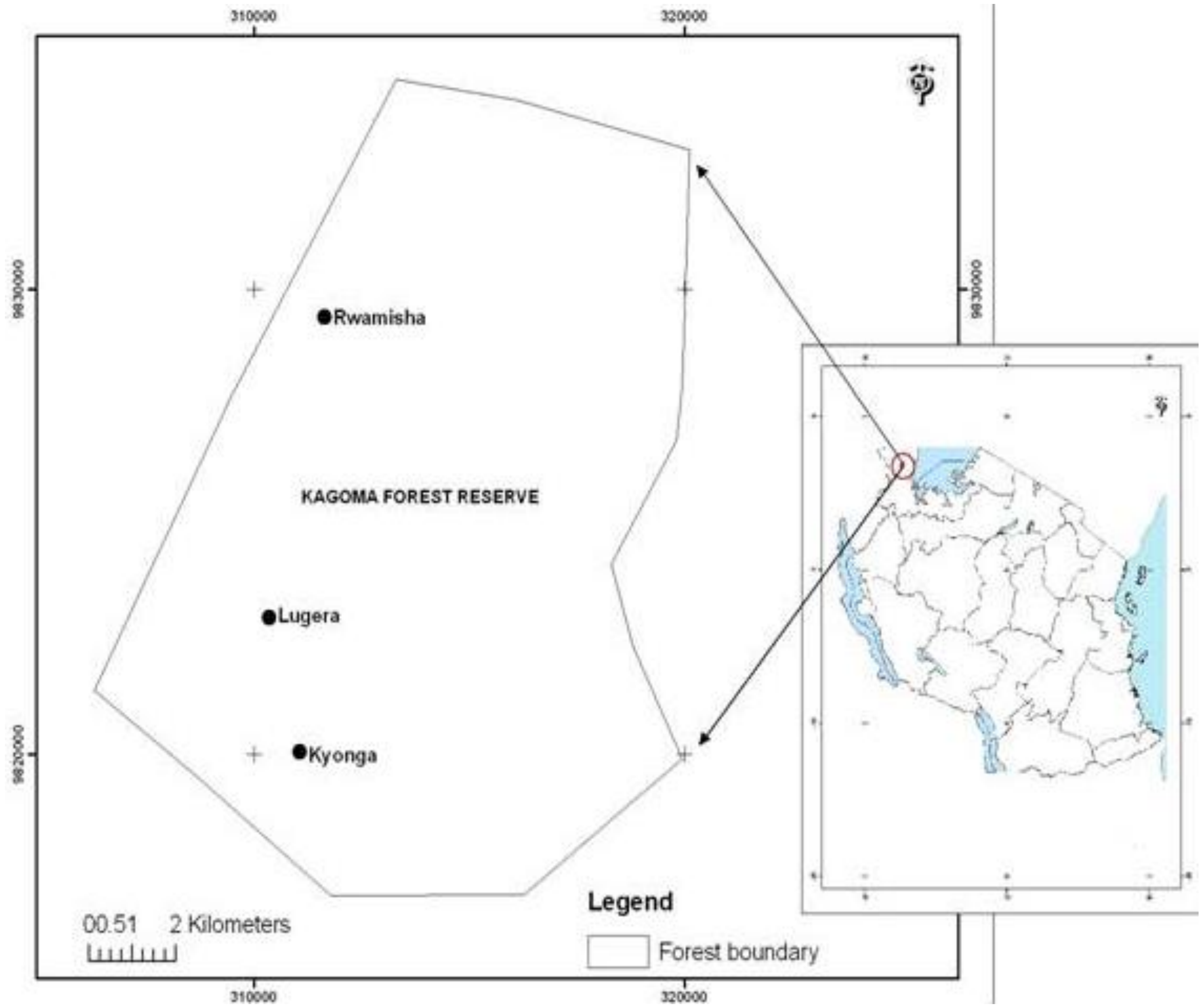

Figure 1. Location of KFR, Tanzania.

and 2010.

MATERIALS AND METHODS

Description and location of the study area

KFR is found in Bukoba Rural District, Kagera Region in Tanzania (Figure 1) and lies within longitudes 1°29'49''S - 1°39'18''S and latitudes 31°18'27''E - 31°19'20''E. The forest is 16,697.92 ha and about 1245 m above sea level. Bukoba Rural District is one of the six districts of the Kagera Region occupied by different tribes but mainly Haya tribe. The geographical coverage of the District is 5282 km² of land and 7925 km² of water, mostly Lake Victoria and including more than 20 islands in the Lake. Major landforms are hills and ridges with a north-south orientation, valleys, uplands and plains. Soil types vary according to location and the common ones were described by Touber and Kanani (1994) as Ferralsols, Fluvisols, Arenosols and Gleysols. Rainfall is very much influenced by topography and the presence of Lake Victoria. A rather steep gradient in total annual rainfall is observed, from 2100 mm along the coast to less than 700 mm towards the interior (Touber and Kanani, 1994). The daily temperatures are relatively low and fluc-tuate between 15°C and 28°C, with an average of 20°C (Hofer et al., 2004). KFR hosts different wildlife species such as elephants (*Loxodonta Africana*), where a large group of 200 elephants which shifted from neighbouring Game Reserves of Burigi and Ibanda Rumanyika due to habitat fragmentations and moved to KFR for refuge. Impala (*Aepyceros melampus*), waterbuck (*Kobus ellipsiprymnus*), roan antelope *(Hippotragus equinus*), birds and other wildlife species are hosted in the KFR (Hofer et al., 2004). There is a large stand of Miombo woodlands and the site is rich in tree species of conservation importance including African Black-wood (*Dalbergia melanoxylon*), Mvule (*Milicia excelsa*) and Muninga (*Pterocarpus angolensis*) thickets.

Analysis of land use and cover changes

Materials used in the study were Landsat 5 TM of 5th June, 1988, Landsat 7 ETM + imagery of 5th June, 1999 and Landsat 7 ETM + of 5th June, 2010. Topographical maps with a scale of 1:50000 were used for geo-referencing Landsat scenes. Global Positioning System (GPS) was used in land use and cover map verification and updating land use and land cover maps to include land use patterns up to 2010. The images were selected based on seasonality of the imageries, spatial resolution 28.5 m, study location and availability of imageries. The land use/cover was captured on the basis of Landsat 5 TM p172r061 scene of August, 1988, Landsat 7 ETM +

p172r061 of June, 1999 and Landsat7 - ETM + p172r061 of June, 2010. The imageries were obtained from the archive of the Geo Network Limited, Dar es Salaam Tanzania, and Sokoine University of Agriculture GIS Laboratory. Topographical sheets with scale of 1:50 000 of 1967 were acquired from the Surveys and Mapping Division of the Ministry of Lands, Housing and Human Settlements Development for geo-referencing Landsat images and during the preparation of the land use/cover interpretation key. The sub-scenes covering the KFR and the neighboring villages were extracted from the above mentioned images. The land cover maps produced by the Africover project in 1995 were also obtained from the Institute of Resource assessment (IRA) of the University of Dar es Salaam. These land use maps were used as base maps during land use and vegetation cover interpretation.

Pre-processing of Landsat data

The 2010 image was geo-referenced using ERDAS IMAGINE 9.1 Software with reference to a topographical map of scale 1:50 000 of the study site. Easily identifiable ground control points on permanent features were used. Thus, image coordinates were transformed into map coordinates as per 36 Universal Transverse Mercator (UTM) zone, projected to UTM, spheroid Clark 1880 and Datum Arc 1960. Images of 1988 and 1999 were geo-referenced using the already geo-referenced image of 2010. Three rectified images were reduced to the size of the study site by using subset command in ERDAS imagine software.

Interpretation of Landsat images

The enhanced images in ERDAS IMAGINE 9.1 Software were converted to ArcGIS 9.3 for interpretation. The image analysis extension in ArcGIS 9.3 helped to sharpen more features for better visual identification of those features of greatest interest in the study area. Different land cover categories were extracted using photo texture. False colour composite was formed using red, green and blue (RGB) for band 4, 3 and 2. An on-screen digitization procedure was used in identifying land covers. The analysis of land cover in KFR was done in an area covering a total of 16 663 hectares and the area was stretched to include a bigger area covering village land bordering the forest in order to relate human factors influencing land cover changes within the forest. The cover classes were determined based on ground truthing data which were used as reference points for each land cover collected from the field by using GPS.

Ground truthing

Land use types identified from the image scenes of 1988, 1999 and 2010 were counterchecked by carrying out fieldwork in the study area in order to update data interpreted from the image. GPS was used to record ground coordinates for different land cover types on the map in order to have correct reference points. The recorded coordinates were then used to transform former land use and vegetation cover types before performing land use vegetation cover change detection for generating the final results.

Land use and vegetation cover change detection

Change detection was performed through the overlay method based on generated vector themes of different years. Change detection was done between datasets of 1988-1999 and 1999-2010 years using year 1999 as a common baseline data year for both periods. The overlay was performed by intersecting feature themes so that the boundaries and attributes of themes were combined to form the derivative output theme. The attribute tables of the output themes were summarized in definition tables and results were exported in MS-Excel Package to compile areas of change for each information category.

Change detection analysis entails finding the type, amount and location of land use changes that are taking place (Yeh et al., 1996). Various algorithms are available for change detection analysis and they can be grouped into two categories namely (a) pixel-to-pixel comparison of multi-temporal images before image classification and (b) post-classification comparison (Jensen, 1996). In this study, a post-classification comparison method was used to assess land use and cover changes. It is the most common approach for comparing data from different sources and dates (Jensen, 1996). The advantage of post-classification comparison is that it bypasses the difficulties associated with the analysis of images acquired at different times of the year and/or by different sensors (Alphan, 2003).

The method has been found to be the most suitable for detecting land cover changes (Wickware and Howarth, 1981); as this enables estimation of the amount, location and nature of change. The only pitfall is that the accuracy of the change maps depends on the accuracy of individual classifications and is subject to error propagation (Zhang and Foody, 2009). The approach identifies changes by comparing independently classified multi-date images on pixel-by-pixel basis using a change detection matrix (Yuan and Elvidge, 1998).

Assessment of the rate of cover change

The estimation for the rate of change for the different covers was computed based on the following formulae (Kashaigili, 2006):

$$\%\ Cover\ change = \frac{Area_{i\,year x} - Area_{i\,year x+1}}{\sum_{i=1}^{n} Area_{i\,year x}}\ x\,100 \quad (1)$$

$$Annual\,rate\ of\ change = \frac{Area_{i\,year x} - Area_{i\,year x+1}}{t_{years}} \quad (2)$$

$$\%\ Annual\ rate\ of\ change = \frac{Area_{i\,year x} - Area_{i\,year x+1}}{Area_{i\,year x}\ x\ t_{years}}\ x\,100 \quad (3)$$

Where: $Area_{i\,year\,x}$ = area of cover i at the first date,
$Area_{i\,year\,x+1}$ = area of cover i at the second date,

$\sum_{i=1}^{n} Area_{i\,year x}$ = total cover area at the first date and

t_{years} = period in years between the first and second scene acquisition data

RESULTS AND DISCUSSION

Land use and land cover class distribution 1988-2010

The land cover maps for 1988, 1999 and 2010 are presented in Figures 2, 3 and 4, respectively. Generally, the maps show the variation in cover between the three

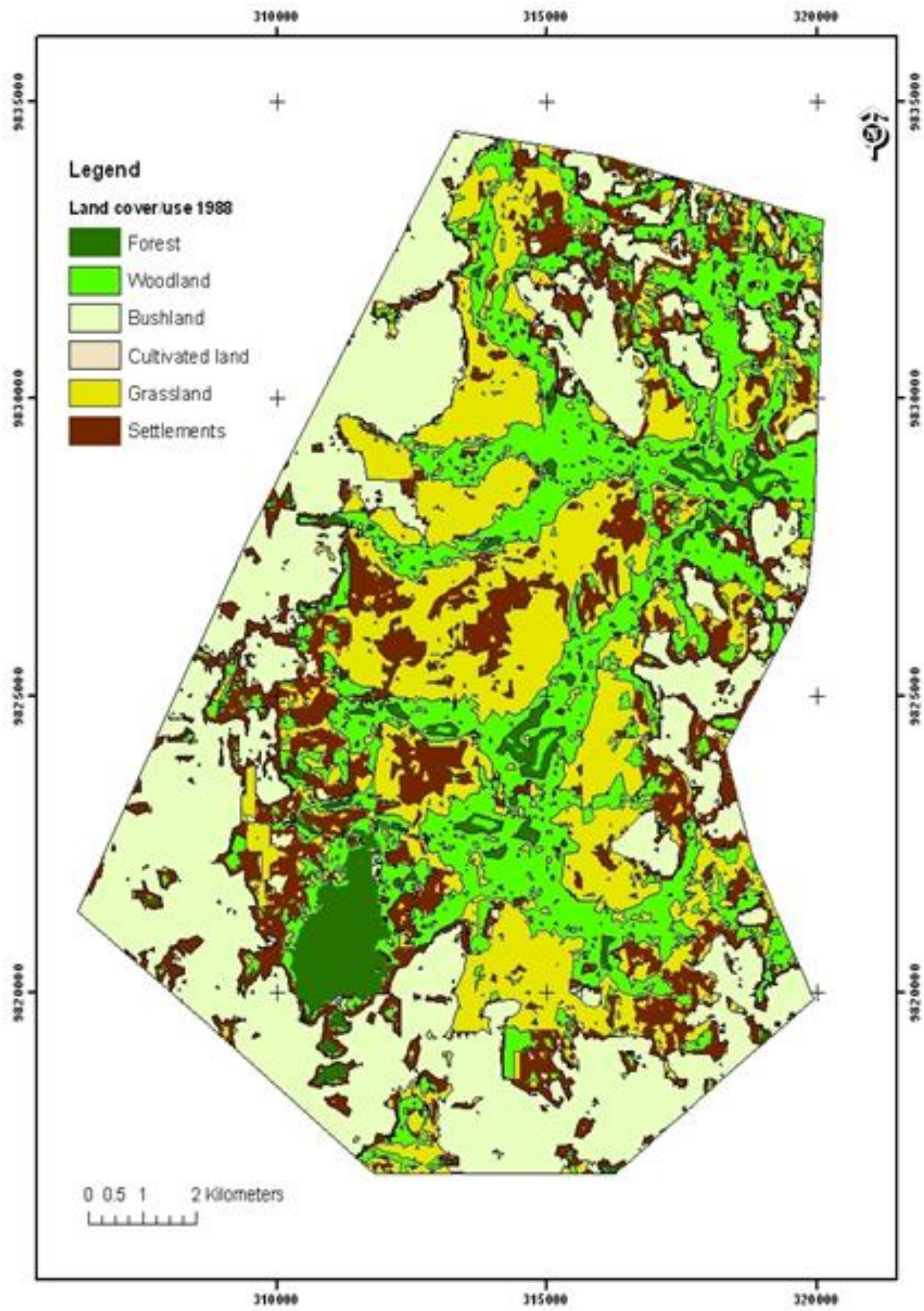

Figure 2. Land use and land cover map of image scene, 1988.

time periods under consideration. It was estimated that vegetation cover was decreasing at the rate of 0.27% per year and there have been significant changes in land use pattern and forest cover in and around KFR. Figure 2 shows that in 1988, bushland dominated the area by covering 27.37% (4570.43 ha) followed by grassland, 24.35% (4065.50 ha), then woodlands, 23.12% (3860.16 ha), settlements, 15.46% (2 581.10 ha), forest, 9.56% (1

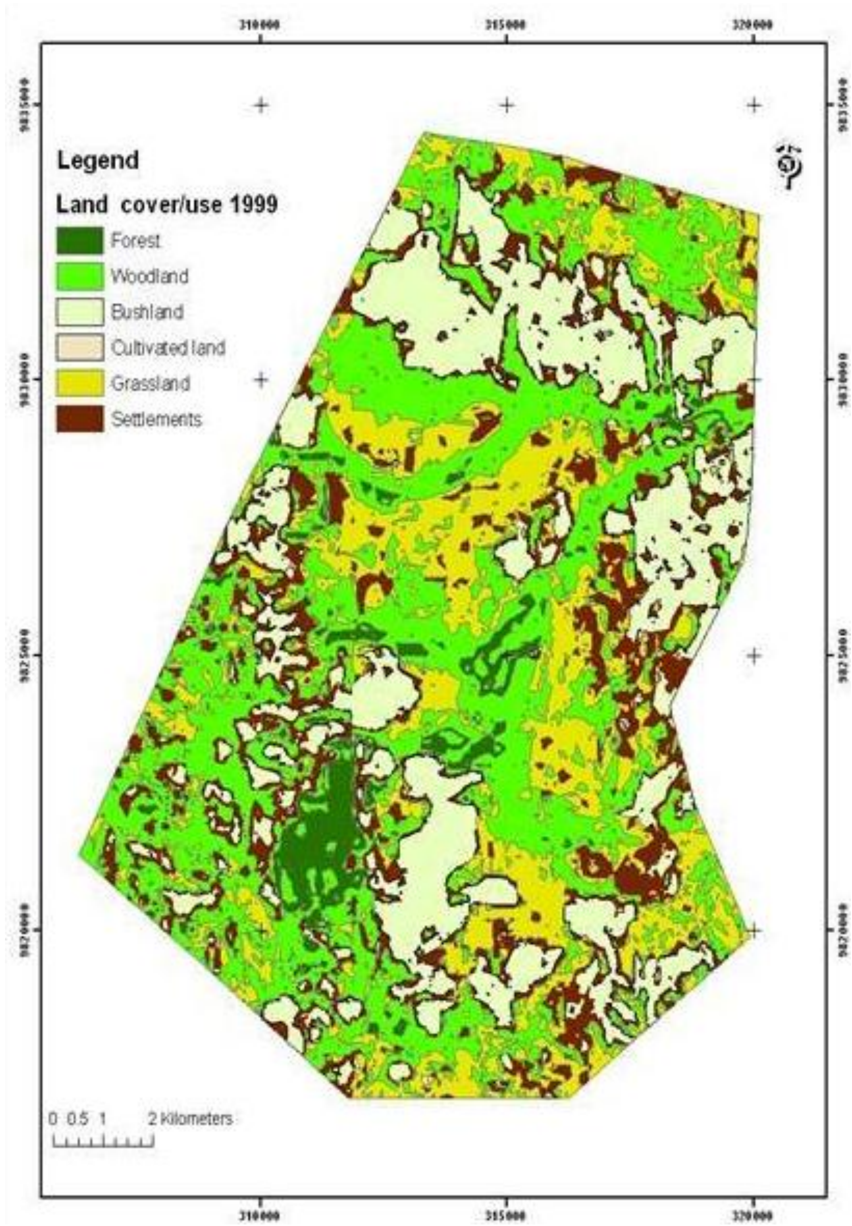

Figure 3. Land use and land cover map of image scene, 1999.

593.20 ha), while cultivated land occupied 0.16% (27.53 ha). Figure 3 shows that in 1999, woodlands occupied the largest area of 28.92% (4 828.85 ha), due to selective logging of the most preferred timber trees in the closed forest. Bushland occupied 23.5% (3 923.43 ha) followed by grassland which covered 21.64% (3614.16 ha) of the forest, settlement area 15.98% (2667.56 ha), then cultivated land 6.07% (1013.31ha) while forest area covered only 3.9% (650.61 ha) of the total area. During this period, woodlands, cultivated land and settlement increased by 968.69 (5.8%), 985.78 (5.9%) and 86.46 ha (0.52%), respectively. The grassland, forest and bushland decreased by 451.34 (2.7%), 942.59 (5.64%) and 647 ha (3.87%), respectively. The results clearly revealed the occurrence of significant land use and vegetation cover transformation from one land use class to another.

In 2010, bushland increased in terms of coverage from 23.5 (3923.43 ha) to 32.25% (5385.9 ha) of the total area and continued to take the lead in coverage of the area followed by settlement area 25.11% (4193.32 ha), grassland 23.15% (3865.39 ha), cultivated lands 12.14% (2027.20 ha), followed by woodlands which occupied 5.95% (993.71 ha), while the forested area covered only 1.39% (232.4 ha) of the total area as shown in Figure 4. During this period (1999-2010), the results showed a substantial decrease in forest cover from 3.9 (650.61 ha) to 1.39% (232.4 ha), while the woodlands decreased from 28.92 (4828.85 ha) to 5.95% (993.71 ha). The results in

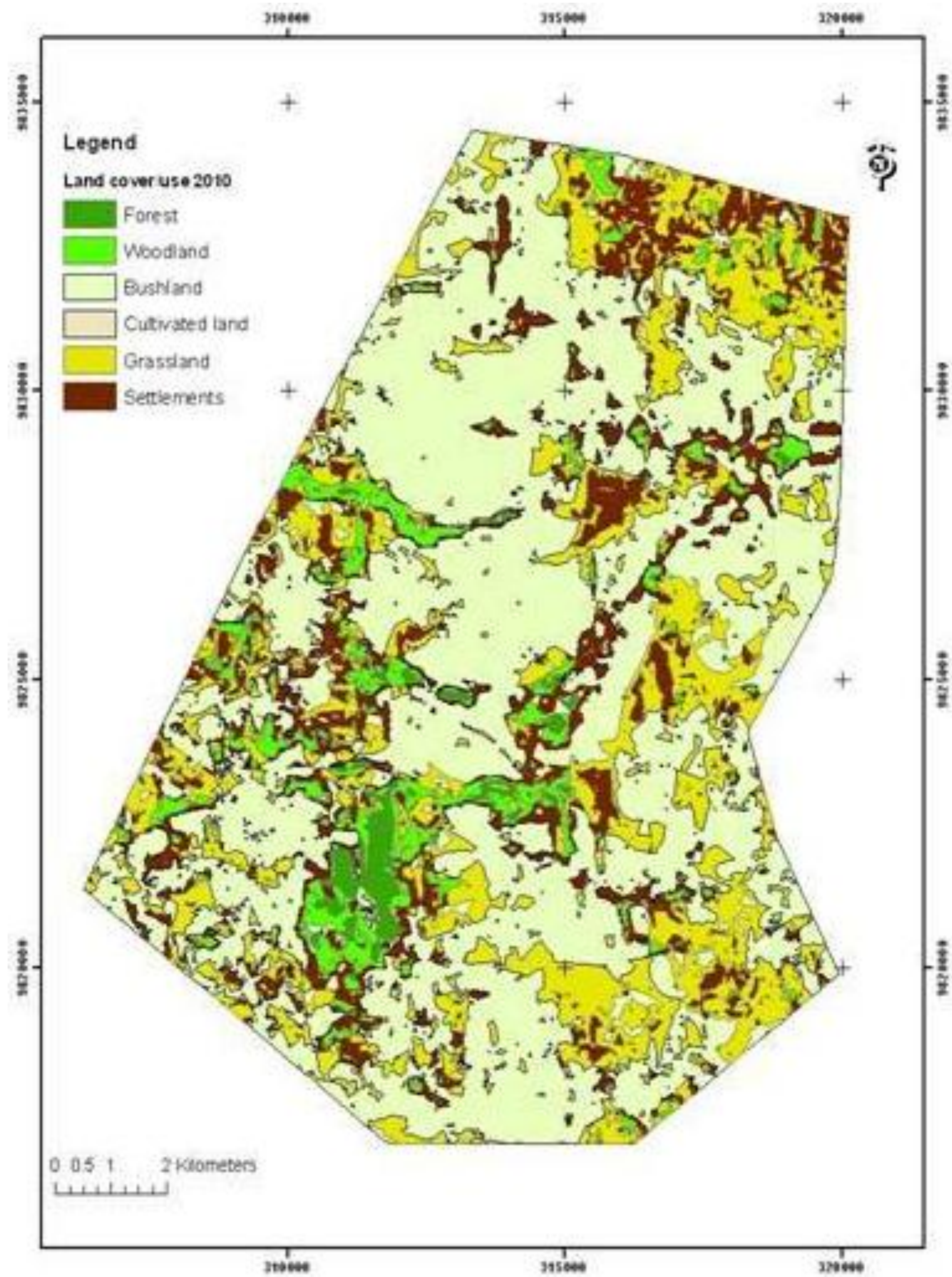

Figure 4. Land use and land cover map of image scene, 2010.

also show that the grassland, cultivated land, bushland and settlement increased by 1.5 (251.23 ha), 6.07 (1013.89 ha), 8.76 (1462.47 ha) and 9.14% (1525.76 ha), respectively. The results clearly indicated that cultivated land and settlement areas increased in both temporal periods. This implies that agricultural activities increased in both periods due to population increase through immigration and increased wealth resulting from livestock keeping at the expense of other land cover types such as forests and woodlands. Agricultural expansion is among the reported activities, which have significant effect on natural vegetation (Ngalande, 2002; Mbonile et al., 2003; Noe, 2003). The continuous increase in cultivated land is also reflected in an increased area under settlements

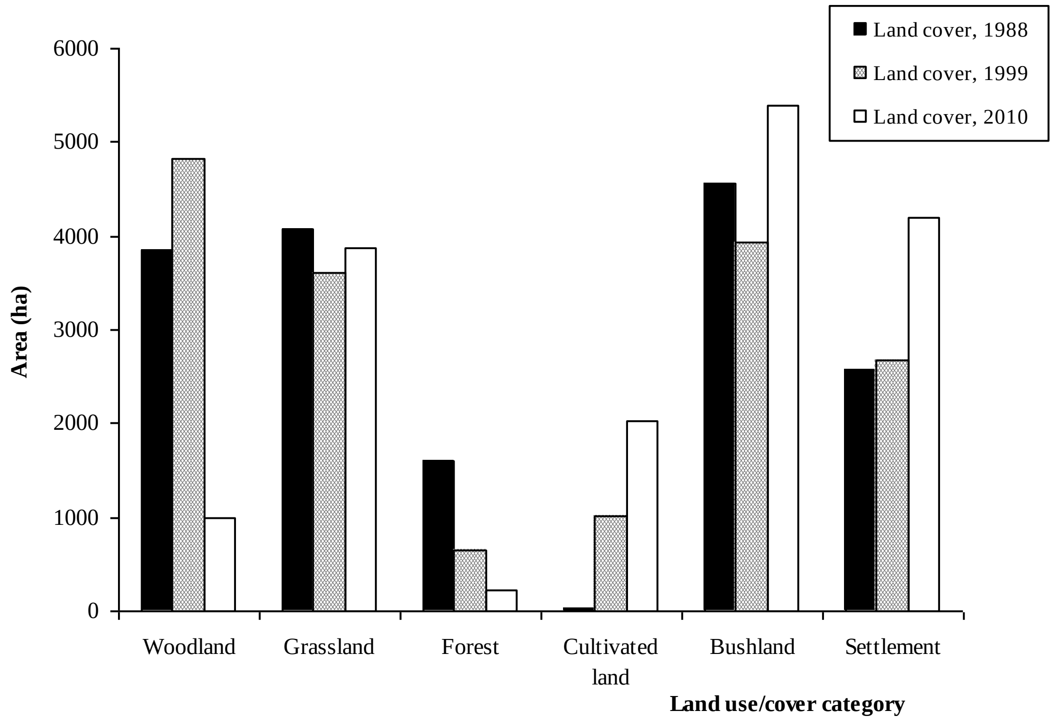

Figure 5. Land use/cover distribution for KFR between 1988 and 2010.

Table 1. Cover area, changed area and the rate of change between 1988 and 1999.

Cover class	Land cover in 1988		Land cover in 1999					
	Area (ha)	Cover (%)	Area (ha)	Cover (%)	Area change (ha)	Cover change (%)	Annual rate of change (ha/year)	Annual rate of change (%/year)
Woodlands	3860.16	23.12	4828.85	28.92	968.69	5.80	88.06	0.53
Grassland	4065.50	24.35	3614.16	21.64	-451.34	-2.70	-41.03	-0.25
Forest	1593.20	9.54	650.61	3.90	-942.59	-5.64	-85.69	-0.51
Cultivated land	27.53	0.16	1013.31	6.07	985.78	5.90	89.62	0.54
Bushland	4570.43	27.37	3923.43	23.50	-647.00	-3.87	-58.82	-0.35
Settlement	2581.10	15.46	2667.56	15.98	86.46	0.52	7.86	0.05
Total area	**16697.92**	**100.00**	**16697.92**	**100.00**				

Table 2. Cover area, changed area and the rate of change between 1999 and 2010.

Cover class	Land cover in 1999		Land cover in 2010					
	Area (ha)	Cover (%)	Area (ha)	Cover (%)	Area change (ha)	Cover change (%)	Annual rate of change (ha/year)	Annual rate of change (%/year)
Woodland	4828.85	28.92	993.71	5.95	-3835.14	-22.97	-348.65	-2.09
Grassland	3614.16	21.64	3865.39	23.15	251.23	1.50	22.84	0.14
Forest	650.61	3.90	232.40	1.39	-418.21	-2.50	-38.02	-0.23
Cultivated land	1013.31	6.07	2027.20	12.14	1013.89	6.07	92.17	0.55
Bushland	3923.43	23.50	5385.90	32.25	1462.47	8.76	132.95	0.80
Settlement	2667.56	15.98	4193.32	25.11	1525.76	9.14	138.71	0.83
Total area	16697.92	100.00	16697.92	100.00				

Table 3. Changes detection matrix in different land use coverage between 1988 and 1999.

Cover in 1988 (ha)	Cover in 1999 (ha)						
	WL	GL	FR	CL	BSL	ST	Total
WL	1289.30 (33.4%)	944.38 (24.5%)	171.18 (4.4%)	3.86 (0.1%)	892.76 (23.1%)	558.69 (14.5%)	3860.16
GL	1403.50 (34.5%)	1060.52 (26.1%)	150.48 (3.7%)	2.40 (0.1%)	848.93 (20.9%)	599.66 (14.7%)	4065.50
FR	223.63 (37.7%)	38.83 (6.5%)	205.01 (34.6%)	20.42 (0.1%)	66.70 (11.2%)	58.60 (9.9%)	1593.20
CL	6.50 (0.6%)	7.95 (0.8%)	0.08 (0.0%)	1000.02 (97.3%)	9.60 (0.9%)	3.41 (0.3%)	1027.53
BSL	1077.85 (23.6%)	1033.67 (22.6%)	61.93 (1.4%)	4.44 (0.1%)	1425.41 (31.2%)	967.12 (21.2%)	4570.43
ST	828.08 (32.1%)	528.80 (20.5%)	61.93(2.4%)	2.19 (0.1%)	680.02(26.3%)	480.08 (18.6%)	2581.10
Total	4828.85	3614.16	650.61	1013.31	3923.43	2667.56	16697.92

WL = Woodland, GL = grassland, FR = forest, CL = cultivated land, BSL = bushland, ST = settlement.

Table 4. Changes detection matrix in different land use coverage between 1999 and 2010.

Cover in 1999 (ha)	Cover in 2010 (ha)						
	WL	GL	FR	CL	BSL	ST	Total
WL	425.45 (11.8%)	1259.57 (24.9%)	53.02(1.5%)	13.02 (10.4%)	2230.27 (31.7%)	847.53 (23.5%)	4828.85
GL	161.12 (24.8%)	917.60 (15.2%)	10.11(1.6%)	8.42 (11.3%)	1024.26 (19.1%)	492.65 (45.0%)	3614.16
FR	134.18 (13.2%)	67.99 (6.7%)	134.63 (13.3%)	344.15 (34.1%)	201.17 (19.9%)	111.81 (11.0%)	650.61
CL	0.46 (0.0%)	2.12 (0.1%)	0.15 (0.0%)	1000.02 (98.3%)	9.03 (0.2%)	1.56 (0.0%)	1013.31
BSL	137.38 (5.1%)	876.89 (32.9%)	17.63 (0.7%)	1002.08 (3.8%)	1557.15 (58.4%)	332.30 (12.5%)	3923.43
ST	35.13 (0.8%)	741.22 (4.4%)	16.87 (0.1%)	2.84 (0.0%)	1364.03 (8.2%)	2407.47 (91.6%)	2667.56
Total	993.71	3865.39	232.40	2027.20	5385.90	4193.32	16697.92

WL=Woodland, GL = grassland, FR = forest, CL = cultivated land, BSL = bushland, ST = settlement.

(Figure 5). Increase in population size leads to demand for more resources and area for cultivation which has an implication on settlements expansion.

As revealed in Table 1, woodlands and settlement increased at a rate of 88.06 ha/year (0.53%/year) and 7.86 ha/year (0.05%/year), respectively over an average period of 11 years (1988 and 1999) assuming a linear increase. The forest cover decreased consistently at a rate of 85.69 ha/year (0.51%/year) over an average period of 11 years (1988 and 1999) assuming a linear decrease. It is possible that the decrease in forest and increase in settlement cover is attributed to increased demand for suitable land for cultivation. This rapid increase might be due to clear felling of trees for firewood, poles, timber and increased settlement and agricultural activities (banana farms and subsistence farming). It is clear from Table 1 that the forest area decreased consistently over 11 years (1988 - 1999) while cultivation increased at a rate of 89.62 ha/year (0.54%/year). Table 2 revealed that grassland, cultivated land, bushland and settlement cover increased between 1999 and 2010. The grassland increased at a rate of 22.84 ha/years (0.14%/year), cultivated land increased at a rate of 92.17 ha/year (0.55%/year), bush land increased at a rate of 132.95 ha/year (0.8%/year) and the settlement cover increased at a rate of 138.71 ha/year (0.83%/year) over an average period of 11 year (1999 and 2010). The expansion of grassland, bushland, settlement and cultivated areas reflects the land use transformation in and around KFR. The increasing population as a result of refugees' influx and immigrants (Berry, 2008) from other districts in Tanzania has had impact on the forest resources in and around KFR.

Change detection matrix of different land use/cover

The change detection of land use/covers in KFR is presented in Table 3. During the period 1988 to 1999, forest decreased by 37.7, 11.2% of forest changed to bushland, 9.9% to settlements, 6.5% bushed grassland, 0.1% of forest was converted to cropland and 34.6% remained unchanged. The woodlands declined the same way where, 24.5% was converted to grassland, 23.1% to bushland, 14.5% was converted to settlements, 0.1% was converted to cropland and 33.4% remain unchanged. About 14.7% of the grassland was converted to settlement area, 0.1% was converted to cropland, 26.1% remain unchanged (Table 3). About 0.1% of bushland was converted to cropland and 21.2% was converted to settlement areas while 31.2% remained unchanged. The results also suggest that 97.3% of the cultivated land remained unchanged for 11 years. Illegal logging and subsistence agriculture are contributing factors to observed land cover changes in the area (Monela and Solberg, 1998). Monela et al. (1998) and Ngalande (2002) found that timber harvesting business in the Miombo woodland has been encouraged by the existence of all-weather roads from the area to other parts of the district and neighboring countries such as Uganda. The analysis of land use and land cover change for the period 1999 - 2010 is provided in Table 4. Forest area changed by 19.9% to bushland, 13.2% to woodlands, 11.0% into settlements, and 6.7% was converted to grasslands, 34.1% of forest was converted to cropland and only 13.2% of the forest remained unchanged.

About 31.2% of the woodlands were converted to bush lands, 24.9% to grassland, 23.5% to settlement areas, 10.4% to cultivated land, 11.8% remained unchanged. Furthermore, 15.2% of the grassland remained unchanged, while 45.0% was converted to settlements, 24.8% to woodlands, 19.1% to bushlands and 11.3% into cultivated lands. The bushlands lost 32.9% to grassland, 3.8% to agriculture, 12.5% to settlements, 0.7% to settlement and 58.4% remained unchanged. Of the cultivated land, 0.2% changed to bushlands, 0.1% changed to grasslands and 98.3% remained unchanged. About 91.6% of settlement areas remained unchanged, while 8.4% changed to bushlands.

Conclusions

The findings revealed that the study area had undergone notable changes in terms of land use and land cover for the period 1988/1999-1999/2010. The results revealed that bushland, grassland, cultivated land and settlement areas have increased in the last twenty three years, where forest land and woodland decreased linearly during the same period. There has been a substantial change in land use and vegetation cover with resultant land degradation over the Kagoma area where the vegetation cover is decreasing at the rate of 45.08 ha (0.27%) per year. The study concludes that there have been significant changes in land use and cover in and around the forest and concerted actions are required to reverse the changes. This situation is likely to reduce wildlife habitat and may also result in forest extinction in future if the situation is left unattended to. The results revealed changes in land use and vegetation cover hence environmental education of local communities at village level is needed to maintain the existing natural vegetation in areas such as this in the country where human activities have seriously affected the resources. The study suggests the establishment and enforcement of different laws and regulations to protect the natural vegetation. It is also suggested the establishment of land use planning could help to improve land tenure and resource use in villages bordering the forest and could substantially reduce the problem of land degradation.

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