Journal of Geography and Regional Planning Vol. 5(6), pp. 151-164, 18 March, 2012
Available online at http://www.academicjournals.org/JGRP
DOI: 10.5897/JGRP11.050
ISSN 2070-1845 ©2012 Academic Journals

Full Length Research Paper

Land-use/cover changes and their drivers on the slopes of Mount Kilimanjaro, Tanzania

Salome B. Misana, Cosmas Sokoni and Milline J. Mbonile

Department of Geography, University of Dar es Salaam, P. O. Box 35049, Dar es Salaam, Tanzania.

Accepted 22 February, 2012

This paper presents the findings of a study that analyzed land use and cover change, their driving forces and the socio-economic implications on the southern and eastern slopes of Mount Kilimanjaro. This study is based on data extracted from remote sensing techniques using 1973, 1984 and 1999/2000 satellite images and household interviews. The major change detected in the study area from satellite images was expansion of cultivation at the expense of natural vegetation. The area under cultivation increased from 54% in 1973 to 62 and 63% in 1984 and 2000, respectively. Expansion and intensification of cultivation were noted particularly in the lowlands while some forest areas in the highlands had become degraded. These changes led to changes in cropping patterns and crop diversification, declined productivity of land and food insecurity. The underlying drivers of these changes were demographic, government policies, economic factors, socio-cultural factors including the land tenure system, institutional factors, technological change and infrastructure development. Investments in irrigation technology, introduction of new crop varieties and government interventions to support the poor are required to improve the productivity of land and reduce the vulnerability of the people to environmental perturbations, including drought.

Key words: Land-use/cover change, Kilimanjaro, agricultural intensification, conversion, diversification.

INTRODUCTION

Land use/cover change has for several decades become a global concern for researchers, given its complexity that requires a deeper understanding of the extent and intensity of the changes, the causes and impacts of such changes on ecosystem goods and services. The concerns arose from the realization that land surface processes and transformations influence climate change and reduce biotic diversity, but in the process, it came to be realized also that land use/cover changes determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations (Lambin et al., 2006; Lambin et al., 2003). In recent years, the numerous researches that have been undertaken have shown that land use/cover change is a much complex process involving situation specific interactions among a large number of factors at different spatial and temporal scales (Lambin et al., 2006; Lambin et al., 2003).

For thousands of years, human activities have transformed the earth's surface by converting natural forests, savannas and steppes into agricultural lands and substantially modifying others with significant consequences for land cover, biodiversity, soil condition and water and sediment flows (Lambin et al., 2003; Turner et al., 1994). Current rates, extents and intensities of land use and cover change, however, are far greater than ever in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales (Ellis, 2010). In fact, their role in environmental change overrides natural changes to ecosystems brought about by climate variations of the past few thousand years (Turner et al., 1990). These land use/cover changes have accelerated in the 20th Century, both in pace and intensity, because of increased intensity of human activities (Ramankutty et al., 2006).

Changes in land use and cover are thus the direct and indirect consequences of human actions to secure essential resources. When misgoverned, the direct drivers may

*Corresponding author. E-mail: smisana@udsm.ac.tz. Tel: +255 22 2850975, +255 784 639595. Fax: +255 22 2850952.

increase the vulnerability of ecosystems and people. As explained by Geist et al. (2006), Geist and Lambin, (2004) and Lambin et al. (2003), these direct drivers, also termed as proximate factors usually operate at the local scale, and originate from intended use of the land by the people for their survival. The proximate factors are, however, often underpinned by underlying driving forces, which include almost any factor that influences human activity. These driving forces are formed by a complex of social, political, economic, demographic, technological, cultural and biophysical variables that constitute structural conditions in human-environmental relations (Geist et al., 2006; Ellis, 2010).

Although, mountains are essential for the survival of humankind because of their resource endowments and thus have a long history of human settlement, they have been threatened by an array of anthropogenic changes, because of their complex and fragile ecosystems. Many have undergone rapid transformation, land use intensification and change such that their ability to provide critical goods and service both to mountain inhabitants and lowland communities has been impaired (Hofer, 2005; Reasoner et al., 2004; Misana, 2001). A good example of such mountains is Mount Kilimanjaro in Tanzania, which has witnessed extensive land use changes for more than 100 years (Soini, 2005; Maro, 1988) with some of its functions, especially the hydrological and ecological functions having been greatly impaired.

Understanding the nature and extent of land use and cover changes as well as assessing the driving forces behind them is essential for explaining past and forecasting future patterns. This paper presents the findings of a study that was undertaken on the southern and eastern slopes of Mount Kilimanjaro to analyze land use/cover changes, their drivers and socio-economic implications. The information generated in this study is central for planning for the sustainable development and management of the mountain ecosystem.

The study applied the political ecology approach (Blakie, 1985; Campbell and Olson, 1991) as its conceptual framework to explain the land use and land management change. This approach emphasizes that land use change results from interactions between society, reflecting economic, social and political processes, and the physical environment (Olson et al., 2004). Such changes may affect biodiversity, water, land productivity and other factors that cumulatively affect the biosphere and communities at large.

The study area

This study was conducted on the southern and eastern slopes of Mount Kilimanjaro (Figure 1). The area has three distinct agro-ecological zones: the highland zone (coffee-banana belt and home-garden area) between 1200 and 1800 m above sea level, the midlands (maize-bean belt) between 900 and 1200 m and the lowlands (extensive livestock farming belt) extending up to 900 m above sea level. Above the coffee-banana belt is a narrow forest strip known as the half-mile forest strip, which was established in 1941 as a social and buffer forest along the lower edge of the montane forest to provide local people with wood and wood products (Kivumbi and Newmark, 1991) Annual rainfall varies with altitude, being 1200 to 2000 mm in the highlands, 1000 to 1200 mm in the midlands and between 400 and 900 mm in the lowlands. The montane zone, which is a forest belt above 1800 m, receives the highest rainfall (in excess of 2000 mm) per year.

Like other mountains in the world, Mount Kilimanjaro is unique in terms of its ecological system, culture and economy. It has a rich natural resource base and substantive biological diversity. Combinations of fertile volcanic soils and favourable climate, have given rise to spectacular development in agriculture in the region. Almost three quarters of the population in the Kilimanjaro region are dependent on the resources provided by the mountain ecosystem. Population density is very high. In 2002, it was over 200 persons/km^2 on the lower slopes and 650 on the higher slopes, with all the southern slopes between 1200 to 1800 m above sea level being the most densely populated zone (Soini, 2005).

MATERIALS AND METHODS

Although land use and cover changes may be observed directly in the field or by remote sensing, investigation of their causes and consequences across a range of spatial and temporal scales generally require the integration of natural and social scientific methods, such as interviews with land managers and expert knowledge (Ellis, 2010). In this study, two methods of data collection were used: (1) a remote sensing/GIS analysis, and (2) 'socio-economic survey using questionnaires to obtain socio-economic-political information. Additional information supporting the interpretations is from literature.

Remote sensing

Landsat time-series analysis

Land use and cover change on the slopes of Mount Kilimanjaro was analysed based on the interpretation of satellite images. Landsat MSS images of 1973 and 1984, and Landsat 7 ETM+ of 1999 and 2000 were used to gather spatial and temporal information that allowed analysis of land use and cover changes. The methodology used is summarized in Figure 2. Each image was first radiometrically and geometrically corrected and geo-referenced to Transverse Mercator geographic projection (UTM Zone 37 South Grid) at the International Livestock Research Institute (ILRI) in Nairobi. False colour composite images were produced at the scale of 1:150000 and hard copies printed to facilitate the visual interpretation process. The 1999 and 2000 images were combined to form a 1999/2000 false colour composite mosaic at the same scale.

The images were visually interpreted based on tone, texture and pattern, and the polygons were hand drawn on the images to show the different land use/cover classes. Table 1 presents the Land use and cover classes used in the study. There were difficulties in the

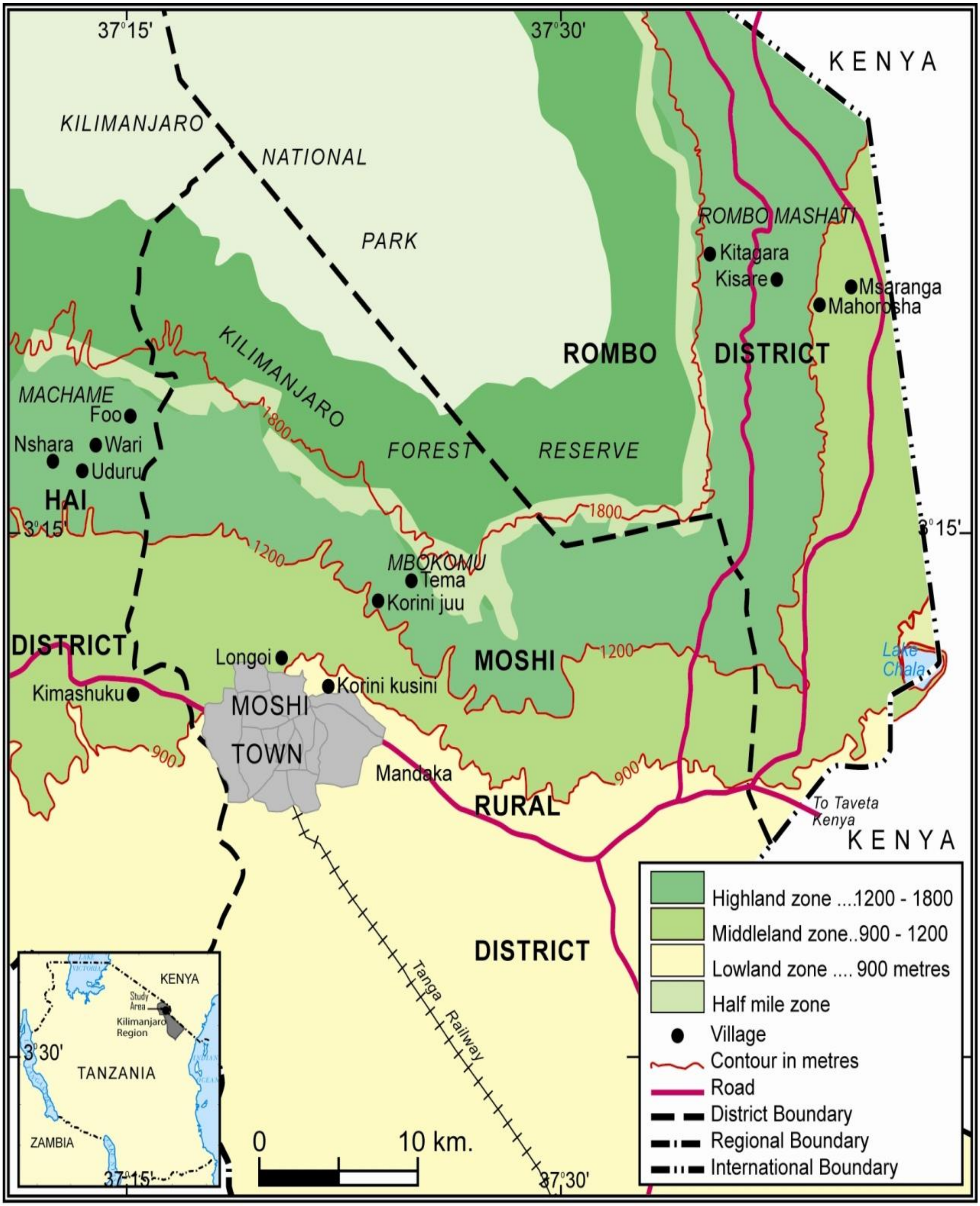

Figure 1. The Agro-ecological zones and location of study villages on Mount Kilimanjaro in Tanzania.

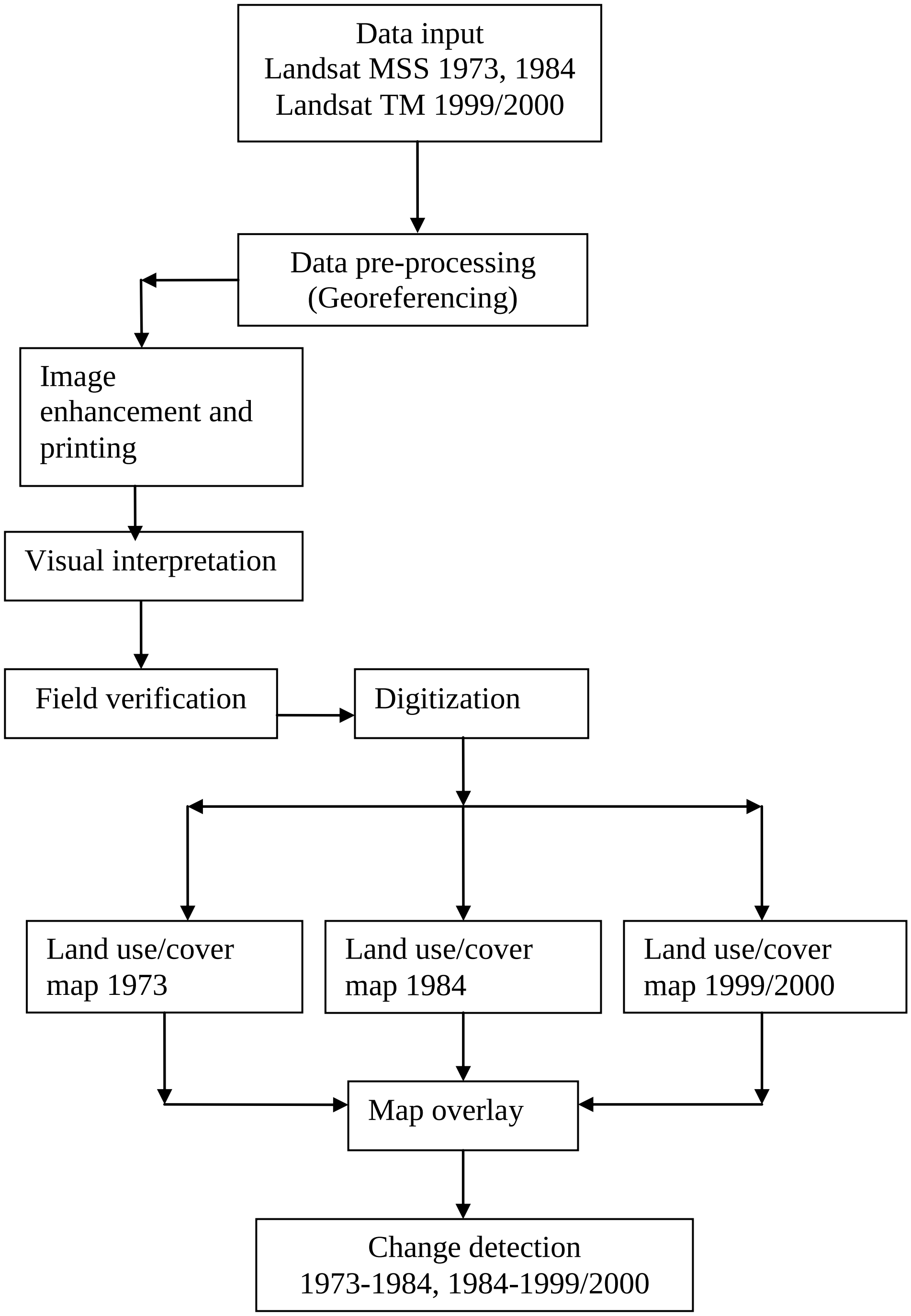

Figure 2. Methodological flow chart for land use/cover change analysis.

interpretation of forests on the 1973 and 1984 images due to cloud cover. Also bush land, grassland and cropland, could not be easily differentiated on the satellite images because of lack of clear boundaries due to their transitional nature and hence some similarities in tone. Thus they had to be combined into one class (Bush-Grass Mix with Cropland). Similarly in the highlands where there is a mixture of herbaceous and tree crops, these could not be easily separated. Thus they had to be combined to form the mixed herbaceous-tree crop cultivation class. Combining the different land use and cover classes, however, obscured differences among them and could therefore be a source of error and inaccuracies in data.

The classes identified on the satellite images were verified (ground-truthed) in the field to check the accuracy of the interpretations. After ground truthing, corrections of the interpreted images were made, the hand drawn polygons were digitized and land use and cover maps produced. Vector maps of towns and villages, which had been digitized from existing village maps, were overlaid on these maps for visual referencing.

Maps showing land use and cover patterns on the slopes of the Mount Kilimanjaro for the three periods were then produced at a scale of 1:250000. Change detection was done by overlaying the maps using geographical information systems. Change detection

Table 1. Land use and cover classes used as a basis satellite imagery interpretation.

Land use/cover class	Description
Natural forest	Medium to high altitude natural forest with very little disturbance. It includes also lowland riverine forest
Degraded forest	Very poor and fragmented patches of forest
Bushland-grassland	Acacia /Commiphora bushland and some wooded grassland with patches of medium height natural grassland,
High-altitude grasses	Natural grassland occurring at high altitudes
Bush-grass mix with cropland	Medium height grasses mixed with shrubs, a few trees and some crops, mainly maize, beans, millet and sorghum. Some areas are also grazed
Mixed herbaceous tree crop cultivation	Areas of farming where there is a mixture of annual crops with perennial tree crops such as coffee, bananas, planted trees and remnants of natural trees
Irrigation (herbaceous crops)	Areas cultivated with annual crops such as rice under irrigation
Plantation (sugarcane)	Cultivation areas planted with sugarcane
Swamps/marsh permanent/seasonal	Areas inundated with water either seasonally or permanently
Swamps/Marsh with cultivation	Areas inundated with water with some patches of cultivation, mainly rice and vegetables in areas that have been drained
Urban areas	All large built up settlement areas officially designated as towns or cities, for example Moshi Town
Airfields	An area designated as an airport, for example Kilimanjaro International Airport

matrices for 1973 to 1984 and 1984 to 2000 were developed from the statistics generated from the overlaid maps to show how much area of one cover category changed to each of the other categories over the two time periods. A historical analysis of land use and cover change aimed at explaining the past and current patterns of observed changes was based on review of literature and available records.

Socio-economic survey

Questionnaires

Socio-economic data were collected along three transects namely the Machame Transect in western Kilimanjaro, Mbokomu Transect in central Kilimanjaro and Rombo Transect in eastern Kilimanjaro. All transects traversed from the highland ecological zone (about 1800 m above sea level) to the lowland ecological zone (about 700 m above sea level) The data were obtained by using a closed and open ended questionnaire, which captured the main economic activities of the people, land ownership, migration, land use change and drivers of change. A total of 280 households were randomly selected along the three transects and the heads of households interviewed. The selection of households closely followed the ecological zones (Highland, middle and lowland ecological zones). Unstructured interviews with key informants who had knowledge of the different dimensions of land use change in the study area provided qualitative information on the nature of land use change over time, particularly since the 1950s and causes of such changes. Such key informants included owners of farms and long time residents in the area, as well as government officials.

RESULTS

Patterns of land use/cover change 1973 to 2000

The summary statistics for land use and cover for 1973, 1984 and 2000 are presented in Table 2. In all the three time periods, the dominant land use/cover was cultivation with mixed herbaceous-tree crop cultivation covering 48.5, 52.8 and 57.2%, of the study area in 1973, 1984 and 2000, respectively. When all cultivation classes were put together, they contributed to more than half of the total area (54% in 1973, 62% in 1984 and 63% in 2000). Bush land-grassland covered 18.3% in 1973, but declined to 12.3 and 11.1% in 1984 and 2000, respectively. Signs of degradation of the natural forest through forest clearance/ regeneration were already

Table 2. Summary of land use and cover coverage for 1973, 1984 and 2000.

Land use/cover class	Area coverage of land use/cover classes					
	1973		1984		2000	
	Ha	%	Ha	%	Ha	%
Natural forest	16472.8*	10.8	30071.0*	19.8	32086.9	21.1
Degraded forest (forest clearing/regeneration)	1374.3	1.0	37.9	0.0	1993.7	1.3
Bushland-grassland	27779.4	18.3	18637.1	12.3	16797.6	11.1
High altitude grasses	2322.3	1.5	4570.1	3	2462.9	1.6
Bush-grass mix with cropland	5442.1	3.6	9032.3	5.9	3789.1	2.5
Mixed herbaceous-tree crop cultivation	73730.6	48.5	80230.4	52.8	86865.9	57.2
Irrigation (herbaceous crops)	366.3	0.2	1915.7	1.3	2330.6	1.5
Plantation (sugarcane)	0.0	0.0	1470.0	1.0	1747.4	1.2
Swamps/marsh permanent /seasonal	2021.3	1.3	2230.6	1.5	1138.2	0.7
Swamps/marsh with cultivation	2112.6	1.4	1060.4	0.7	1029.6	0.7
Urban areas	245.0	0.2	564.1	0.4	1552.9	1.0
Airfields	31.4	0.0	45.9	0.0	78.8	0.1
Cloud cover	19975.8	13.2	2008.4	1.3	0.0	0.0
Total	151873.9	100	151873.9	100	151873.9	100

*Underestimate due to cloud cover.

Table 3. Absolute change (in hectares and percent) of land use/cover classes 1973 to 2000.

Land use/cover class	Net cover change					
	1973-1984		1984-2000		1973-2000	
	Ha	%	Ha	%	Ha	%
Natural forest	+13598.2*	+82.5	+2015.9*	+6.7	+15614.1	+94.8
Degraded forest (forest clearing/regeneration)	-1336.4	-97.2	+1955.8	+5160.4	+619.4	+45.1
Bushland-grassland	-9142.3	-32.9	-1839.5	-9.9	-10981.8	-39.5
High altitude grasses	+2247.8	+96.8	-2107.2	-46.1	+140.6	+6.0
Bush-grass mix with cropland	+3068	+56.4	-4721	-55.5	-1653	-30.4
Mixed herbaceous-tree crop cultivation	+6499.8	+8.8	+6635.5	+8.3	+13135.3	+17.8
Irrigation (herbaceous crops)	+1549.4	+422.9	+414.9	+21.6	+1964.3	+536.2
Plantation (sugarcane)	+1470.0	+100.0	+277.4	+18.9	+1747.4	+100
Swamps/marsh permanent /seasonal	+209.3	+10.3	-1092.4	-48.9	-883.1	-43.7
Swamps/marsh with cultivation	-1052.2	-30.8	-30.8	-2.9	-1083	-51.3
Urban areas	+319.1	+130.2	+988.8	+175.3	+1307.9	+533.8
Airfields	+14.5	+46.2	+32.9	+71.7	+47.4	+150.9
Cloud cover	-17967.4	-89.9	-2008.4	-100.0	-19975.8	-100

*Underestimate due to cloud cover.

evident by 1973.

Table 3 gives the absolute change in land use/cover classes while Figure 3 illustrates the land use and cover changes for the periods 1973, 1984 and 2000. The major change observed in the study area was expansion of cultivation down the slopes and the replacement of natural vegetation by cultivated land. It was evident that mixed herbaceous-tree crop cultivation had expanded at the expense of natural vegetation. It increased by 8.8% between 1973 and 1984 and by 8.3% between 1984 and 2000.

Although it was difficult to interpret the changes in forest cover because of cloud cover on the 1973 and 1984 satellite images, there was evidence of some forest loss in the south-eastern and eastern parts of the forest. This was reflected in an increase in patches of degraded forest characterized by forest clearings and regeneration particularly along the edges of the half-mile strip. In 1973, the degraded forest covered 1,374.3 ha but by 2000 it had increased to 1993.7 ha. Some of the forest areas

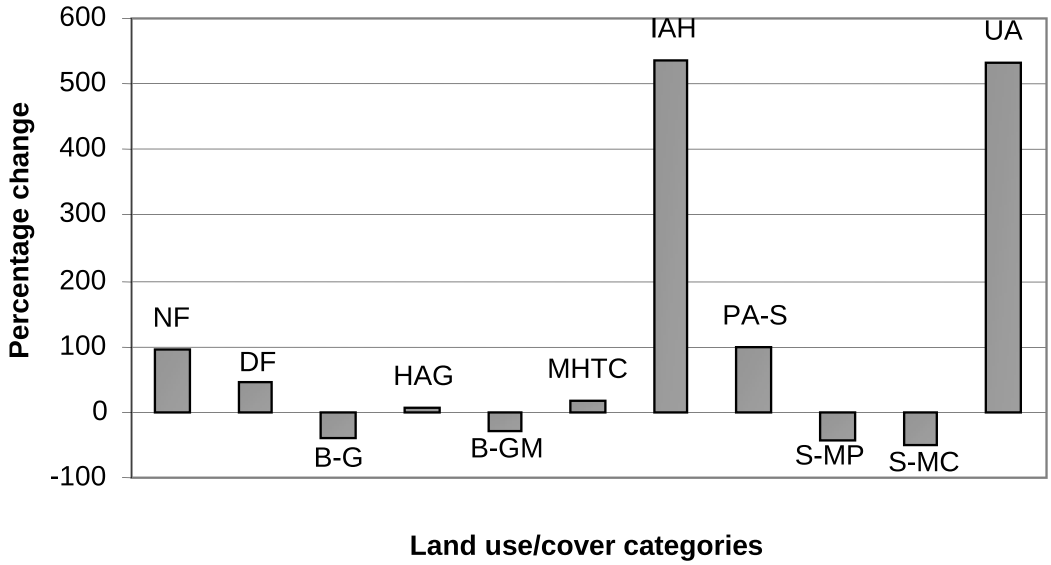

Figure 3. Land use and cover changes on the southern slopes of Mt. Kilimanjaro 1973 to 2000 (Key: NF – natural forest, DF – degraded forest, B-G – bushland-grassland, HAG – high altitude grasses, B-GM – bush-grass mix with cropland, MHTC – mixed herbaceous tree crop cultivation, IAH – irrigation agriculture (herbaceous crops), PA-S – plantation agriculture (sugarcane), S-MP – swamps/marsh (permanent or seasonal), S-MC – swamps/marsh with cultivation, UA – urban area.

Table 4. Land use/cover change detection matrix 1973 to1984.

	B-G	B-G C	MH-TC	IA	PSG
B-G	10368.0	4713.2	9198.7	1168.6	87.5
B-G C	963.3	864.1	3164.3	0.0	0.0
MH-TC	828.0	0.0	64177.9	480.0	1382.6
IA	0.0	0.0	263.4	102.8	0.0
PSG	0.0	0.0	0.0	0.0	0.0

Key: B-G – Bushland-grassland, B-G C – Bush-grass mix with crops; MHTC – Mixed herbaceous-tree crop cultivation; IA - Irrigated agriculture; PSG – Plantation (sugarcane).

had been converted to cultivation, the dominant land use pattern in the highlands being cultivation with tree crops.

There was a general decline of bush land-grassland from 27,779.4 ha in 1973 to 16797.6 ha in 2000, a decrease of 39.5% (Table 2). A similar pattern could be observed between 1973 and 1984, with a decrease of 32.9%. A greater part of the bush land-grassland vegetation (about 9198 ha) was converted to mixed, herbaceous-tree crop cultivation between 1973 and 1984 (Table 4) compared to 6915.9 ha between 1984 and 2000 (Table 5). The bush-grass mix with cropland increased by 56.4% between 1973 and 1984 but decreased by 55.5% between 1984 and 2000.

The increase in the earlier period was due to the conversion of 4713.2 ha of bushland-grassland to bush-grass mix with cropland while its decrease in the latter period could be explained by the conversion of 6072.4 ha to mixed herbaceous-tree crop cultivation. Most of the bush land had been replaced by cultivated fields. Only tiny fragments of bush land remained in the cultivated fields.

Questionnaire findings

Information from the questionnaire interviews confirmed that the slopes of Mount Kilimanjaro were already settled and intensively cultivated even before 1950. Majority of the people (about 94%) who acquired land between 1950 and 2001 acquired land that was already under-cultivation. The survey also revealed that the main occupation of most of the people (86.3%) was crop farming while livestock grazing was a secondary occupation. It is no wonder, therefore, that cultivation classes dominated the landscape during the different time periods. While coffee, bananas and vegetables were

Table 5. Land use/cover change detection matrix 1984 to 2000.

	B-G	B-G C	MH-TC	IA	PSG
B-G	9286.9	229.5	6915.9	0.1	
B-G C	1483.4	776.2	6072.4	194.9	374.6
MH-TC	1795.7	2606.8	71039.1	1069.8	186.8
IA	26.7	1130.5	0.0	756.1	0.1
PSG	0.4	0.0	83.5	202.9	1182.7

Key: B-G – Bushland-grassland; B-G C - Bush-grass mix with crops; MHTC – Mixed herbaceous-tree crop cultivation; IA - Irrigated agriculture; PSG – Plantation (sugarcane).

the predominant crops in the highlands, maize and beans were the major crops in the lowlands. The predominance of coffee as a cash crop had, however, declined in recent years due to declined prices and high production costs brought about by high prices of inputs due to removal of subsidies and hence inability of most farmers to buy the required pesticides to fight Coffee Berry disease. In fact, only 44% of the households indicated that coffee was their first cash crop. Vegetables and non-traditional cash crops like maize, beans and rice seemed to have increased their economic role in the region, thus attracting more farmers to grow the crops.

Driving forces

Different underlying driving factors have operated in the study area at different time periods (Figure 4) and led to significant changes in land use and land cover. These include demographic factors, government policies, institutional factors, economic factors, socio-cultural factors, technological factors as well as infrastructure development. Though each factor is discussed separately subsequently, it does not mean that they acted in isolation; rather they interacted at different spatial and temporal scales to bring about the observed changes.

Demographic factors

Population growth, migration and increasing population density are the major demographic factors that have influenced the utilization of land and other natural resources in the Kilimanjaro region resulting in land use/cover changes. Available records indicate that although the first immigrants moved to the area at least some five to six hundred years ago (Maro, 1998), significant changes are said to have occurred in the early nineteenth century. This is the time when the Chagga (the Bantu speakers who descended from immigrants of various tribes who migrated into the once forested foothills of the mountain) settled there and began the process of transforming the original forest into an agroforestry system (Soini, 2005; Maro, 1988; Fernandes et al., 1984).

Population around Mount Kilimanjaro increased from 128,443 in 1921 to 230,667 in 1948, and by the 1960s, it had reached to over 476,000 (Mbonile et al., 2003; Maro, 1988). In 2002 the population had increased to 1,049,819 while estimates for 2010 showed that the population would be 1,636,000 (National Bureau of Statistics, 2011, 2006). The population growth rate ranged from 1.9 to 4.5% for the region. Because of population growth caused by both natural increase and immigration, population density increased tremendously over the years from 26 persons per km^2 in the 1920s to over 200 on the lower slopes and 650 on the higher slopes in 2002 (Soini, 2005; 2002a). Such high densities led to increased pressure on natural resources including land, resulting in a drastic decrease in farm size, scarcity and fragmentation of land, out-migration and expansion of agriculture into the lowlands. Due to increased and severe population pressure, and the resulting land use intensification and expansion, the southern slopes experienced significant environmental changes, declining productivity and loss of natural habitats (Soini, 2002a). Consequently, farmers were forced to settle in the less fertile lowlands, which previously were used only for supplementary food production. This marked the beginning of agricultural expansion and conversion of grazing areas in the lowlands.

Government policies

Land use change on Mount Kilimanjaro has also been influenced by Government policies and legislations, which date back to 19th century. The policies and legal frameworks introduced by colonial governments since 1898 led to alienation of land for European settlements, large scale farms and ranches, making it unavailable for the local population. This affected the distribution of land and reduced the land available to the local population for cultivation and grazing. The colonial agricultural policies, which encouraged the introduction of coffee and establishment of large scale coffee estates in the 1930s,

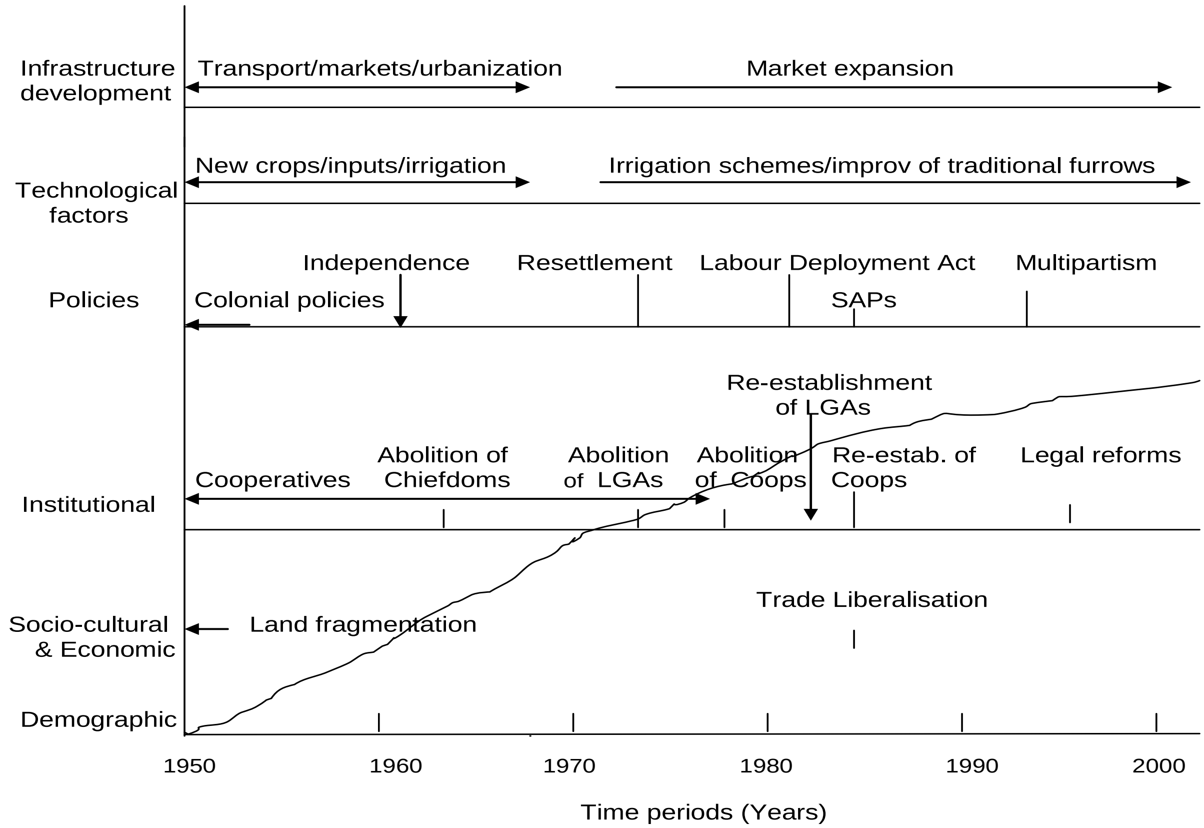

Figure 4. Underlying drivers of land use/cover change at different time scales.

not only disrupted pre-existing land use but also led to significant land use and coverchanges (Soini, 2005; Olson et al., 2004). For example, pastures above the inhabited area as well as share of the homegardens reserved for animal grazing were taken over for coffee growing, with extensive grazing giving way to stall feeding indoors (Maro, 1988; Devenne et al., 2006). Coffee plantations also replaced nearly all the remaining forest leaving few shade trees, mainly *Albizia schimperiana* and *Rauvolfia caffra* (Devenne et al., 2006). The post independence policies, including the Villagisation policy, the 1983 Agricultural policy and the Labour Deployment Act of 1983 led to the resettlement of people and expansion of agriculture in the lowlands.

Economic factors

The economic factors that have influenced land use change have operated at both local and international scales and have all been influenced by government policies and programmes (Olson et al., 2004). These factors include globalization and demand for coffee in the world market, the structural adjustment programme (SAP) of the mid-1983, availability and price of agricul tural inputs and technology, and price and marketability of commodities, among others.

Coffee was first introduced by Missionaries in 1890s and initially it was grown by only a few people, but with the export of the crop since 1898, coffee growers slowly increased in number, turning large proportions of their lands into coffee farms (Iliffe, 1969). The commercialization of coffee was in response to the world market demand for tropical raw materials by German Industrialists (Iliffe, 1969). This slowly led to the expansion of coffee cultivation in the home gardens and establishment of large scale coffee estates especially from the 1930s.

In the 1980s, the Government of Tanzania started implementing structural adjustment policies, which encompassed liberalization of markets, removal of subsidies on inputs and price reforms among others (Bagachwa et al., 1995), which have all affected land use and resource management practices. For example, the removal of subsidies hiked the price of farm inputs especially for coffee, which requires a lot of insecticides, making them unaffordable to farmers. Consequently, coffee production went down due to coffee berry disease, forcing farmers to turn to maize, beans and more recently to vegetables, most of which are grown in the lowlands. Removal of subsidies of veterinary inputs, on the other hand, reduced the ability of the local communities to access them leading to decimation of livestock populations following outbreaks of diseases such as rinderpest. This in turn forced a number of pastoralists to diversify their livelihood systems by growing crops pushing livestock grazing towards more fragile land. At the international level, the fluctuations of foreign currency exchange rates have resulted in negative terms of trade and lowered local commodity prices forcing farmers on Mount Kilimanjaro to abandon coffee, their traditional cash crop, in favour of tomatoes and vegetables. This has also been supported by the liberalization of markets, which has increased market access for non-traditional crops, like maize and vegetables.

Institutional factors

Institutional factors that have influenced land use and cover changes relate mainly to establishment of cooperatives during the colonial period, abolition of chiefdoms in 1962, abolition of local government authorities (LGAs) in 1972 and their re-establishment in 1982, as well as the abolition of cooperatives in 1976 and their re-establishment in 1984 (Figure 4). These institutions had been central to the development of the local economy and management of resources. For example, during the colonial period, the traditional rulers (chiefs) were the custodians of natural resources. The abolishment of chiefdoms in 1962 changed completely the structure of the local government and land tenure as the traditional rulers no longer had powers or control over the management of the resources. This opened doors for abuse of the resources particularly in the halfmile forest strip whose management focus changed from a social to a commercial forest with more trees being cut than planted.

Cooperatives were a driving force of development in the Kilimanjaro region. They facilitated intensification by supporting farmers in terms of making inputs available to them and establishing markets. Before their abolition in 1976, the cooperatives were able to buy inputs in bulk and from well known lower price suppliers and thus helped to reduce production costs for the coffee growers (Maghimbi, 2007). They also established markets for their members such that in years of low demand, their members would not be thrown out of production (Iliffe, 1969). Their abolition greatly affected coffee production because farmers could no longer buy chemical inputs and coffee became infected by pests and diseases like the Coffee Berry disease. The decline of coffee production led to uprooting of coffee by farmers in the 1980s and substituting it with maize and vegetables that would provide them money within a short period. The re-establishment of cooperatives in 1984 coincided with trade liberalization, which allowed private dealers to compete with cooperatives. Although most farmers opted for the private market that paid money promptly, they had no security of supply of inputs like fertilizers and pesticides. Thus eventually, they abandoned their coffee farms and some coffee trees turned into bushes (Maddox et al., 1996; Mbonile, 1999) while others were uprooted and replaced by vegetables and maize, and more recently by flowers in large scale farms. Maghimbi (2007) also associates the problem of low coffee prices and high input prices to the abolition of cooperatives though the low prices could also be attributed to high supply of coffee to the world market from other regions.

Socio-cultural factors

Socio-cultural factors like land inheritance have led to land fragmentation leading to some plots of land being less productive and highly degraded. Due to the inheritance and the prevailing land tenure system, there has been fragmentation and re-distribution of land holdings between generations. This is because culturally all sons are supposed to inherit some family land leading to splitting of farms into smaller and smaller holdings. In situations where the father had no land other than the mixed coffee/banana farm where the family lived, the youngest son would be favoured by getting the largest share of the land (Maghimbi, 2007). Consequently, farms have dwindled in size to such an extent that even with fair or high prices, returns would still be small. Today, much of the land in the upper and middle zones, especially in Moshi Rural and Hai Districts, is so fragmented that there is no further room for expansion. This has forced farmers to intensify and diversify production or revert to the lowlands for their survival. Off-farm activities have also become very crucial, with some youths migrating to urban areas in search of business opportunities.

Technological factors

Technological factors being referred to here are mainly agricultural innovations (newly introduced crops), inputs and technology, which led to intensification and expansion (extensification) of cultivation in the highlands and the lowlands, respectively. The introduction of banana crop during the 16th century, maize, cassava, sweet potatoes, sugar cane and later on coffee brought by missionaries in the late 19th century all led to intensification of agriculture in the highlands (Soini, 2005). The original forest was transformed into an agroforestry system in which multipurpose trees were intercropped with food crops, with pulses being used to regenerate the soil after the millet crop (Soini, 2005). Slowly some indigenous trees were replaced with exotic trees, such as *Grevillea robusta*, which were planted to provide shade for coffee (Fernandes, et al., 1984). The agroforestry system was supported by a sophisticated irrigation system using traditional irrigation furrows. The introduction of coffee in 1883 by missionaries and its large scale adoption by the Chaggas since the 1930s, brought with it large scale transformation of the landscape and significant land use changes. Upland grazing lands were converted to large scale coffee estates necessitating stall feeding of cattle (Soini, 2005). Grazing areas, sweet potato fields and even *Dracaena* groves, which were set aside for burials and sacrifices, were all converted to home gardens where coffee was intercropped with bananas and trees, resulting in reduced production of maize, millet and beans in the high and middle lands (Soini, 2005; Fernandes et al., 1984). Agriculture and settlements increasingly spread to steep river valleys and down the slopes to the lowlands, with cultivation of food crops being pushed to the lower slopes. This marked the beginning of agricultural expansion (extensification) in the lowlands, a situation that was compounded further by high population density and scarcity of land in the highlands. Thus, Maro (1988) identifies two steps in the intensification of agriculture on the mountain slopes. The 1st step happening from the 16th Century to 1930s is when the fertile highlands were converted to home gardens and small fields of food crops followed by establishment of large scale coffee estates. The second step is when part of food crops production was moved to the lower slopes since the 1930s.

With income from coffee, farmers started to purchase improved cattle especially dairy breeds, a phenomenon which has become a common trend in the area. Thus the local breeds were pushed to the lowlands. Although for long time coffee remained as the base of the Chagga economy, the decline in prices on the world market since the 1960s forced many farmers to diversify by engaging in non farm activities such as sale of milk and diversifying crops. Expansion of crop production, especially maize, beans, rice and vegetables in the lowlands has been supported by establishment of irrigation schemes and improvement of the traditional irrigation furrows in recent years.

Infrastructure development

Infrastructure development and market access have influenced to a great extent production of crops and livestock in the study area. Investments in transport infrastructure in the study area since colonial times and its location relative to markets made it easily accessible and competitive in the supplying of produce relative to other areas. Local markets also expanded with urbanization, thus increasing market opportunities. With the liberalization of trade in recent years, markets have expanded even further to include those outside the country. Thus for example, the significance of vegetables, especially tomatoes in the production economy increased in recent times due to availability and accessibility of markets brought about by liberalization of markets, the largest market being Kenya.

Socio-economic impacts

Upper slopes and middle zones

Due to land scarcity, lack of markets and the limited opportunity to expand agriculture in the upper and middle zones, the younger generation has been forced to look for better and more productive ways of earning their living. Increasingly, the young people are becoming involved in off-farm activities away from their homes as a livelihood strategy because of difficulties in agriculture. As a result, there is, according to Soini (2002b: 17) “an acute problem of the highland population getting older and older as the younger generation moves away from the area to urban areas and other regions in the country”. Mbonile (2003) noted a category of absentee farmers made up of people who were pushed from the slopes of the mountain due to scarcity of land and the decline of crop productivity or price, but they retained their home gardens by tradition. Such plots were being maintained by elderly parents.

Farmers in the uplands have, on the other hand, opted to diversify their crop production. Thus cropping patterns have changed over time, with less coffee and bananas and more maize, beans, vegetables and flowers. Many homesteads have vegetable gardens in their immediate surroundings, with such crops as cabbage, tomatoes, onions, eggplant and sweet pepper. This has been exacerbated by the declining international crop prices, particularly for coffee, and terms of trade for agricultural commodities.

In recent years, particularly since the 1980s, vegetables have been seen to provide a higher and more stable income than coffee, which for a very long time has been a major cash crop in the area. In response to this, some farmers have uprooted their coffee trees and planted vegetables and horticultural crops like tomatoes and onions. In some areas, previous large coffee estates have been planted with flowers, which are grown mainly for the export market. Some of these estates have now been converted to maize farms. Maghimbi (2007) observes that farmers in Kilimanjaro now produce only about 5000 tons of coffee per year, which is less than half the yearly amount produced, on average, between the 1950s and the early 1990s.

Lower slopes

Diversification of crops has also occurred in the lower slopes where tomatoes and other vegetables have replaced cotton as a major cash crop. Because of the drastic drop of the price of cotton since the 1980s, many people especially in Makuyuni ward turned to the production of coffee (Sevaldsen, 1997). But due to the increased scarcity of water and the fact that many people did not have the required shady environment to make the

Table 6. Proportion of households that produce insufficient food in a normal year.

Zone	Village	No of households	Households with food insecurity	Percent
Highlands	Foo	40	11	27.5
	Wari	24	2	8.3
	Tema	41	4	9.7
	Korini Juu	28	5	17.8
	Katangara	35	19	54.3
Middle	Uduru	18	2	12.5
	Nshara	18	3	16.7
	Korini Kusini	15	6	40.0
	Kisale	21	15	71.4
Lowlands	Kimashuku	0	0	0.0
	Longoi	14	1	7.1
	Mandaka	19	3	15.8
	Mahorosha / Msaranga	7	5	71.4
Total	13	280	76	27.1

Source: Mbonile et al. (2003).

coffee trees thrive many farmers have been forced to turn to new crops such as tomatoes, other vegetables and sunflower. Since the mid-1980s, tomatoes have gained significance as a cash crop and have even become the number one cash crop for people in Makuyuni ward (Sevaldsen, 1997). However, because of the perishability of the crop and the limited market as many people have become involved in the production of the crop, the prices are no longer favourable, although they are still much better than the coffee and cotton prices.

As a result of changes in the cropping system, scarcity of land, declined productivity of the land and water shortage food insecurity has become very common and widespread in households in all agro-ecological zones, especially in some of the highly degraded villages such as Foo in Machame, as well as Katangara and Kisale in Rombo. Mbonile et al. (2003) observed that about 27.1% of the households interviewed were not able to produce sufficient food in a normal year and therefore faced food insecurity (Table 6). The situation is worse in the lowlands where farmers have become poorer with fewer livelihood options than highland farmers. Soini (2002b) observed that in the lowlands where most farmers lacked the necessary assets to build their life upon, some people were claimed to have died of hunger during the droughts in 2000 when both the short and long rains failed.

The expansion of agriculture into the lowlands wheremost of the bush land-grassland areas were being used as grazing lands by the nomadic Maasai pastoralists, has also significantly reduced the grazing lands over the years as depicted from the bush land-grassland decline. The encroachment of farming into the riverine and swamp areas and on the mountain slopes has reduced access to dry season grazing lands. This has increased the intensity of grazing in response to declining pastures leading to degradation of the land. This coupled with droughts and diseases, has led to loss of livelihoods and made the livelihood systems for many herders become less sustainable. Many pastoralists have become poorer. Consequently they have diversified into farming and have become sedentary in some areas. The expansion of agriculture into the traditional grazing areas has also been a major source of conflict between farmers and pastoralists.

DISCUSSION

The general trend of land use/cover change between 1973 and 2000 has mainly been intensification of cultivation and expansion of the latter to the lowlands. Although the extent of forest in the montane zone does not seem to have changed much, some areas that were under natural forest, especially in the half mile strip, were now under cultivation or degraded types of vegetation. A forest decrease of about 41 km^2 between 1952 and 1982 was also reported by Yanda and Shishira (2001) while William (2002) reported a decline in forest cover of 38.9 km^2 in the half mile strip on the southern slopes between1952 and 1982. This clearly demonstrates that loss and/or conversion of forests on the mountain was not a recent phenomenon; already it was happening by the 1950s.

As reported by Soini (2005), much of the present day cultivated land in the highlands was initially forestland. The first immigrants transformed the original forests into an agroforestry system with much of the forests being cleared for settlement and cultivation of bananas, which were introduced into the area from South-east Asia by early traders between the 8 and 16th Century although numerous other cultivars were introduced from other regions of Africa and world at large (Montlahuc and Philippson, 2006). Only useful tree species such as *Cordia abyssinica, Albizia schimperana*, *Caesalpinia decapetala, Rauvolfia caffra* and *Datura arborea* among others were retained in the farms mainly for timber, fuelwood, fodder and mulch production, bee forage, as live fences and as pest repellants while less useful species disappeared gradually (Fernandes et al., 1984; Devenne et al., 2006).

Although in this study the area under cultivation was observed to have increased between 1973 and 2000, the rate of increase was very small compared to other use and cover classes. For example, there were only 8 and 1% increase between 1973 and 1984 and between 1984 and 2000, respectively. This may be explained by land scarcity and the limited opportunity to expand agriculture, particularly in the upper and middle zones. Only in-filling of cultivation into valleys, hills and other pieces of land that had not yet been cropped was being undertaken. These findings are supported by Soini (2002a) who observed that most open spaces in the highlands had been taken by 1982 for building new home gardens; thus there was no room for further expansion. Soini (2002b) further observed that the home garden area on the upper slopes had not expanded downwards since the 1960s due to land scarcity. This means that much of the transformation in the upper zones took place in earlier periods, most likely between 1930s and 1960 when coffee production was at its height.

This study has also shown that much of the cultivation had extended to the lowlands and plains where more bush land was being converted to agricultural land for food production resulting in a decline of bush land-grassland vegetation. Patches of bush land vegetation remained only on top of volcanic hills or in areas not suitable for cultivation because of shallow soils. These results correspond to the findings of Soini (2005) who observed a decrease of bush land from 40% in the 1960s to only 7% of the entire Kirua Vunjo Division in 2000. Soini (2002a) further observed that more bush land had been opened up for food production by 1982 in response to increased population pressure on the upper slopes. This could therefore explain the decrease by 32.9% of bush land-grassland vegetation between 1973 and 1984 compared to 9.9% between 1984 and 2000, and the increase by 56.4% of the bush-grass mix with cropland during the same period observed in this study.

While the drivers of these changes are multi-faceted, they represent the interaction between biophysical and societal processes over space and time and reflect interdependencies among scales, from local, national and international scales. A good example is when the demand for coffee at the global market influenced coffee production at the local level, with expansion of the area under cultivation resulting in transformation of landscapes. This economic factor interacted with technological advances in irrigation and colonial policies which were supportive of coffee production to bring about the landscape changes. What this implies is that no single factor can operate in isolation in influencing land use and cover changes. Rather, as reported by Lambin et al. (2006) the whole process of land use and cover change involves situation specific interactions among a large number of factors at different spatial and temporal scales. Therefore any investigation of the drivers of land use and land cover changes must consider them in their totality.

Conclusion

Major changes in land use/cover have occurred on the southern slopes of Mount Kilimanjaro. The major land use/cover change observed was expansion of cultivation down the slopes and the replacement of natural vegetation by cultivated land. These changes have taken place at different time scales and were driven by variety of demographic, social-cultural, economic, political, technological, institutional and infrastructural development processes. In response to these changes, many farmers have diversified their crop production with the youths opting for non-farm activities outside their homes as a livelihood strategy. For the majority of the farmers, however, land scarcity continues to be a major constraint to agricultural expansion, and in the face of climate change, they are likely to become even more vulnerable to drought and hunger.

Given the limited opportunities that farmers on Mount Kilimanjro have to diversify their livelihood options, and in order to increase productivity of the land intensification of agriculture on the small plots of land and investment in off-farm activities seem to be the only way out. Youths need to be trained and imparted with skills that they need to effectively engage in off-farm activities. Technological advancement is also needed to help the farmers increase their crop production. Such advancement requires investment in irrigation technology, either by improving the existing traditional irrigation furrows or establishing new irrigation schemes for rice and maize cultivation especially in the lowlands to support the small scale farmers. It also requires investment in reclamation of degraded land as well as research and experimentation for new crop varieties, such as improved high yielding coffee varieties, vanilla and others that need to be introduced in the area in order to diversify crop production and provide the farmers with additional sources of income. Government interventions are also needed to support the poor and marginalized pastoralists who have increasingly been pushed out of production because of reduced grazing lands and increasing drought. What is required is for the pastoralists to move away from their tradition of keeping large herds of cattle to keeping a few improved dairy cows that are high yielding in terms of milk production.

ACKNOWLEDGEMENTS

The authors acknowledged the financial support from the United Nations Environment Programme (UNEP)/Division of Global Environment Facility (GEF) Coordination, without which this study would not have been possible. Authors are also thankful to the International Livestock Research Institute for managing the fund as well as Jennifer Olson and David Campbell for coordinating the LUCID project. The entire LUCID team and the International Advisory Board of the project are also acknowledged for their valuable comments and cooperation during the duration of the study.

REFERENCES

Bagachwa MSD, Shechambo F, Sosovele H, Kulindwa K, Naho A, Cromwell E (1995). Structural Adjustment and Sustainable Development in Tanzania, Dar es Salaam University Press, Dares Salaam. pp. 64-65.

Blackie P (1985). The Political Economy of Soil Erosion in Developing Countries. Longman Group Limited, Essex.

Campbell DJ, Olson JM (1991). Environment and development in Kenya: flying the kite in Kajiado District. The Centen. Rev., 35(2): 295-314.

Devenne F, Chapuis O, Bart F (2006). Chagga farming systems, strengths and stumbling blocks. In Bart F and Mbonile MJ (Ed) Kilimanjaro: Mountain, Memory, Modernity. Mkuki na Nyota Publishers, Dares Salaam, pp. 177-199.

Ellis E (2010). Land-use and land-cover change. http://www.eoearth.org/article/Land-use_and land-cover_change. (Accessed 21/9/2011).

Fernandes ECM, O'kting'ati A, Maghembe J (1984). The Chagga homegardens: a multistoried agroforestry cropping system on Mt. Kilimanjaro (Northern Tanzania). Agrof. Syst., 2: 73-86.

Geist H, McConnel W, Lambin EF, Moran E, Alves D, Rudel T (2006). Causes and Trajectories of land-use/cover change. In Lambin EF and Geist H (Eds). Land-Use and Land-Cover Change. Springer-Verlag, Berlin, pp. 41-70.

Geist HJ, Lambin EF (2004). Dynamic causal patterns of desertification, BioSci., 54(9): 817-829.

Hofer T (2005). Introduction: the International Year of Mountains challenge and opportunity for mountain research. In Huber UM, Bugmann KM, Harald KM and Reasoner MA (Ed) Global Change and Mountain Regions: An Overview of Current Knowledge. Springer, AA Dordrecht, pp. 1-8.

Iliffe J (1969). The age of improvement and differentiation. In Kimambo IN and Temu AJ (Eds). A History of Tanzania. East African Publishing House, Nairobi, pp. 123-160.

Kivumbi CO, Newmark WD (1991).The history of the half-mile strip on

Mount Kilimanjaro. In Newmark WD (Ed). The Conservation of Mount Kilimanjaro. IUCN, Gland. pp. 81-86.

Lambin EF, Geist H, Rindfuss RR (2006). Introduction: local processes with global impacts. In Lambin EF, Geist H (Eds). Land-Use and Land-Cover Change. Springer-Verlag, Berlin, pp 1-8.
Lambin EF, Geist HJ, Lepers E (2003). Dynamics of land-use and land-cover change in tropical regions. Annu. Rev. Environ. Resour., 28: 205-241.

Maghimbi S (2007). Recent changes in crop patterns in the Kilimanjaro Region of Tanzania: the decline of coffee and the rise of maize and rice. African Study Monographs Suppl, 35: 73-83.

Maro PS (1988). Agricultural land management under population pressure: the Kilimanjaro experience, Tanzania. Mount. Res. Dev. J., 8: 273-282.

Mbonile MJ, Misana SB, Sokoni C (2003). Land Use Change Patterns and Root Causes on the Southern Slopes of Mount Kilimanjaro. Land Use Change, Impacts and Dynamics (LUCID) Project Working Paper 25. International Livestock Research Institute, Nairobi, p. 17, 29.

Mbonile MJ (2003). Absentee Farmers and Change of Land Management on Mount Kilimanjaro, Tanzania. Land Use Change, Impacts and Dynamics (LUCID) Project Working paper 24 International Livestock Research Institute, Nairobi, p. 9.

Mbonile MJ (1999). Population dynamics on the slopes of Mount Kilimanjaro. in Mount Kilimanjaro: Land and Environmental Management. French Institute for Research in Africa, Nairobi, pp. 18-23.

Misana SB (2001). Empowering local communities to manage resources. Proceedings of the WMS 2001 International Symposium on Mountains of the World in preparation for the International Year of Mountains (IYM 2002). Interlaken. CD ROM. p. 3.

Montlahuc ML, Philippson G (2006). Before coffee, pre-colonial agricultural glossary (Translated by Martin T). In Bart F, Mbonile MJ (Ed) Kilimanjaro: Mountain, Memory, Modernity. Mkuki na Nyota Publishers, Dares Salaam, pp. 59-69.

National Bureau of Statistics (2006). Tanzania Census 2002: Analytical Report Volume X. Ministry of Planning, Economy and Empowerment, Dar es Salaam, p. 15.

National Bureau of Statistics (2011). Tanzania in Figures 2010. www.nbs.go.tz/pdf/Tanzania_in_Figures 2010.Pdf.

Olson JM, Misana S, Campbell DJ, Mbonile M, Mugisha S (2004). The Spatial Patterns and Root Causes of Land Use Change in East Africa. Land Use Change, Impacts and Dynamics (LUCID) Project Working Paper 47. Int. Livest. Res. Inst., Nairobi, p. 3-14.

Ramankutty N, Graumlich L, Achard F, alves D, Chhabra A, DeFries RS, Foley JA, Geist H, Houghton RA, Goldewijk KK, Lambin EF, Millington A, Rasmussen K, Reid RS, Turner II BL (2006). Global land-cover change: recent progress, remaining challenges. In Lambin EF and Geist H (Eds). Land-Use and Land-Cover Change. Springer-Verlag, Berlin. pp. 9-39.

Reasoner M, Bugmann H, Schaaf T (2004). Background and concepts for collaborative work: global change research in Mountain Biosphere Reserves. In Lee C and Schaaf T (Ed). Global Change Research in Mountain Biosphere Reserves. Proceedings of the international launching Workshop. UNESCO, Paris, pp. 11-18

Sevaldsen K (1997). Competing Interests and Growing Demand for Water. Irrigation in the Lowlands of Kilimanjaro: The Case of Makuyuni Ward. Msc Thesis, Norwegian University of Science and Technology, Trondheim.

Soini E (2005). Land use change patterns and livelihood dynamics on the slopes of Mt. Kilimanjaro, Tanzania. Agric. Syst., 85: 306-323.

Soini E (2002a). Changing landscapes on the southern slopes of Mt. Kilimanjaro, Tanzania: an aerial photo interpretation between 1961 and 2000. Working Paper 2002-1. World Agroforestry Centre (ICRAF), Nairobi. p. 1-3.

Soini E (2002b). Livelihoods on the Southern Slopes of Mt. Kilimanjaro, Tanzania: Challenges and Opportunities in the Chagga Homegarden System. Working, 2002-2003. World Agroforestry Centre (ICRAF), Nairobi. p. 14, 17.

Turner II BL, Meyer WB, Skole DL (1994). Global land-use/land cover change: towards an integrated Program of Study. Ambio 23(1): 91-95.

Turner II BL, Kasperson RE, Meyer WB, Dow K, Golding D, Kasperson JX, Mitchell RC, Ratick SJ (1990). Two types of global environmental change: definitional and spatial-scale issues in their human dimensions. Global Environmental Change: Human. Policy Dimensions, 1(1): 14-22.

William CMP (2002). The Implications of Changes in Land Use on Forests and biodiversity: A case of Half Mile strip on Mount Kilimanjaro, Tanzania. MA Dissertation, University of Dar es Salaam, p. 23.

Yanda PZ, Shishira EK (2001). Forestry conservation and resource utilisation on the southern slopes of Mount Kilimanjaro: Trends, conflicts and resolutions. In Ngana JO (Ed). Water Resources Management in the Pangani River Basin: Challenges and Opportunities. Dar es Salaam University Press, Dares Salaam, pp. 104-117.