Evaluation of Land Use Change in Kiboko Watershed, Kenya

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Abstract

The Kiboko watershed has undergone changes in land use in the recent past which is suspected to have caused degradation by soil loss. The changes in the land use were quantified through a comprehensive land use change detection carried out between 1980 and 2009 for Kiboko Watershed, using Geographic Information Systems (GIS). This was achieved through spatial analysis on each of the land use map and statistical analysis by means of an overlay operation to examine land use pattern in the watershed. The results showed that both Irrigated and cultivated land increased from 0Ha (0%) in 1980 to 395Ha (0.1%) and 16,955Ha (3%) in 2009 respectively, while shifting cultivation, rangeland, and residential land increased from 10,784Ha (2%), 568,7657Ha (88%) and 0Ha (0%), in 1980 to 16,955Ha (3%), 574,502Ha (89%), and 773Ha (0%) in 2009 respectively. In the same period, agro-pastoralism decreased from 66,206 Ha (10%) to 22,680Ha (4%). It can be concluded that the area under cultivation for crop production and residential land are on increasing trend while that of range land is on a decreasing trend.

Key Words: Climate Change, Land Degradation, River Kiboko Watershed, GIS, Sedimentation, Spatial Analysis

INTRODUCTION

Land use change is one of the main drivers of many environmental change processes and may influence a variety of natural phenomena and ecological processes, including soil conditions, water runoff, soil erosion and biodiversity. Such changes can affect catchment hydrology by altering the rates of interception, infiltration, evapo-transpiration and groundwater recharge, resulting in changes in timing and amounts of surface and river runoff (Miller *et al*., 2002; Jewitt *et al*., 2004). It also affects the distribution and pattern of sedimentation (Kasai *et al*., 2005). Land use change is expected to have a greater impact on soil erosion than climate change (Valentin *et al*., 2005) which therefore represents an important sediment source in a range of environments and an effective links for transferring runoff and sediment to water bodies.

A multitude of natural factors can lead to changes in land use (DeFries & Eshleman, 2004; Randhir & Tsvetkova, 2011). These factors range from seasonal variations in land cover characteristics and natural maturation of forest stands to long-term habitat adjustments as a result of climatic change. Land use changes can also result from various human activities such as urbanization, deforestation and land use conversion to agricultural lands and forest management practices.

At present, physical expansion of urban areas and extensive use of land mainly for agricultural purposes are the main causes of land use change in the developing countries. Poor land management has degraded vast amounts of land, reduced our ability to produce enough food and is a major threat to rural livelihoods in many developing countries. Land cover change directly affects ecological landscape functions and processes with far-reaching consequences on biodiversity and natural resources (Hansen *et al.*, 2004). The potential for surface runoff and soil erosion has been mostly affected by land use and cultivation (Van Rompaey *et al*., 2002).

Historic land use change has affected hydrology in the tropical region as once dominant forests have been converted to agricultural land in many areas. Changes of land use exert a significant influence on the relations of rainfall-runoff and/or runoff-sediment and alter soil and water loss accordingly (Kim, 2002). In addition, land use change and hydrological correction works may alter substantially the sediment delivery and water discharge of a catchment, influencing the geo-morphological processes within the river bed, and sometimes inducing non-desirable processes for river management (Kondolf *et al*., 2002).

In the last decades severe land use changes occurred in tropical countries, due to increasing population and their demand for food resources (Lambin *et al*., 2001). Changes in land use occur continuously in response to population growth and changes in the primary production activities that are vital to Kenya's overall economy. The Kiboko catchment in semi-arid lands of Kenya has undergone land cover changes since 1940s caused by forest clearing which has lead to increase in land degradation. Several workers have described the situation currently evident in this region as a ―poverty trap‖, in which the highly subsistence population living on degraded soils receives low income, affords low or no farm inputs, and consequently get low crop yields (GoK, 2004). Land degradation is linked to a number of inter-related problems such as land use, accelerated erosion, rapid population growth and poverty (Opio-Odongo *et al*., 1993). However, land–use and accelerated soil erosion due to agricultural mismanagement, overgrazing and deforestation have been identified as the major causes of land degradation in this region. As a result, crop yields in the region have dropped, siltation has increased thereby reducing the storage capacity and lifespan of rivers and water reservoirs in the region, and turbidity of water sources has increased resulting in frequent outbreaks of waterborne diseases in the region.

Land use history is very important to assess current landscape conditions as land use legacies can influence many other processes that are observed in the present time. In highly managed lands such as agricultural areas or pasture, historical management can help to explain current conditions of soils and water. Historical land use influences watersheds by cumulative effects on ecological systems, which should be considered in environmental planning and management. Thus, there is urgent need to understand the changing land use in order to restore the productivity of land and water resources.

MATERIALS AND METHODS

Description of the Study Area

Kiboko watershed has an area of approximately 5,947km^2 and lies between latitudes of 1.71° and 2.63° South and longitudes of 36.71° and 37.94° East of Makueni and Kajiado counties in the Semi-Arid lands of Kenya (Figure 1). The watershed receives an annual average rainfall of 600mm. The highest rains fall along a northwest/southeast trending axis of the Chyulu hills. It is characterized by bimodal rainfall with long rainy season occurring from March to May and short season from October to December. Evapo-transpiration ranges from 1550-2500mm per year. The minimum and maximum temperatures vary from 13 to 42^{o}C with very dry months being June to September. The topography of the watershed is undulating with a mean slope of 4.9% (Figure 3). Most streams feeding River Kiboko have their sources from major hill masses in the watershed including Chyulu and Kilima hills. River Kiboko originates from Selenkei, Nomau and Chyulu hills and served by several seasonal streams. The major streams feeding River kiboko are; River Ketetemai, River Olesugut, River Elkeryai, River Nosidan and River Oletukai.

The soils are medium-textured ferrasols with the dominant type being moderately deep chromic luvisols. The soils along the Chyulu Hills are volcanic while the soils in the extensive lowlands are characterized by basement complex sandy. The soil drainage is good with a medium texture and deep with low acidity. The predominant land use is shrub land grassland which covers more than 90% of the watershed.

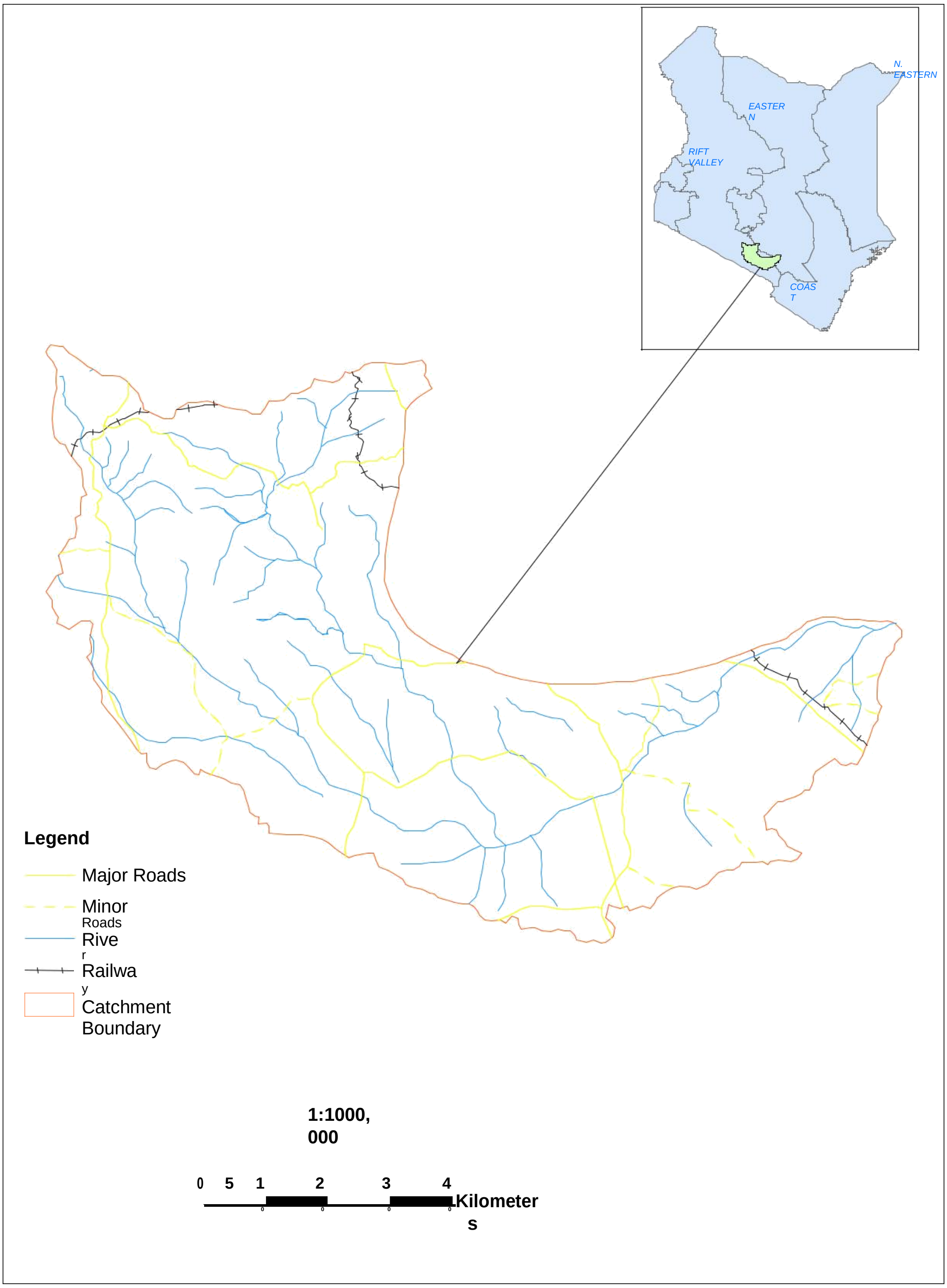

Figure 1. Location of the study area showing boundary, roads and major streams

Land Use Data

The land use maps of the watershed area for 1980, 1986, and 2000 in the scale of 1:750,000 were obtained from Kenya Soil Survey database. However reclassification of the land use maps was done to represent the land use according to the specific land cover types.

To generate land use map for 2009, the landsat Satellite image for 2009 for the study area at 90M x 90M resolution was obtained from Regional Centre for Mapping of Resources for Development and the boundary of the watershed was delineated. The image was then classified to obtain information on the watershed land use. The 2009 image was classified using the maximum likelihood classification algorithm with a pixel-based approach and its classification accuracy was assessed by collecting ground truth data on field visits in November, 2010. Samples were chosen in each polygon and ground GPS readings of the same taken. At each sample point and in each polygon, the constituent plant or crop species were identified and canopy cover readings were noted to make informed decision on the land use types.

Spatial analysis were carried on each of the land use maps through rasterization into pixels, classification based on a real distribution of land use and finally statistical analysis of the maps by means of an overlay operation to examine land use pattern in the watershed using GIS technology for the last three decades.

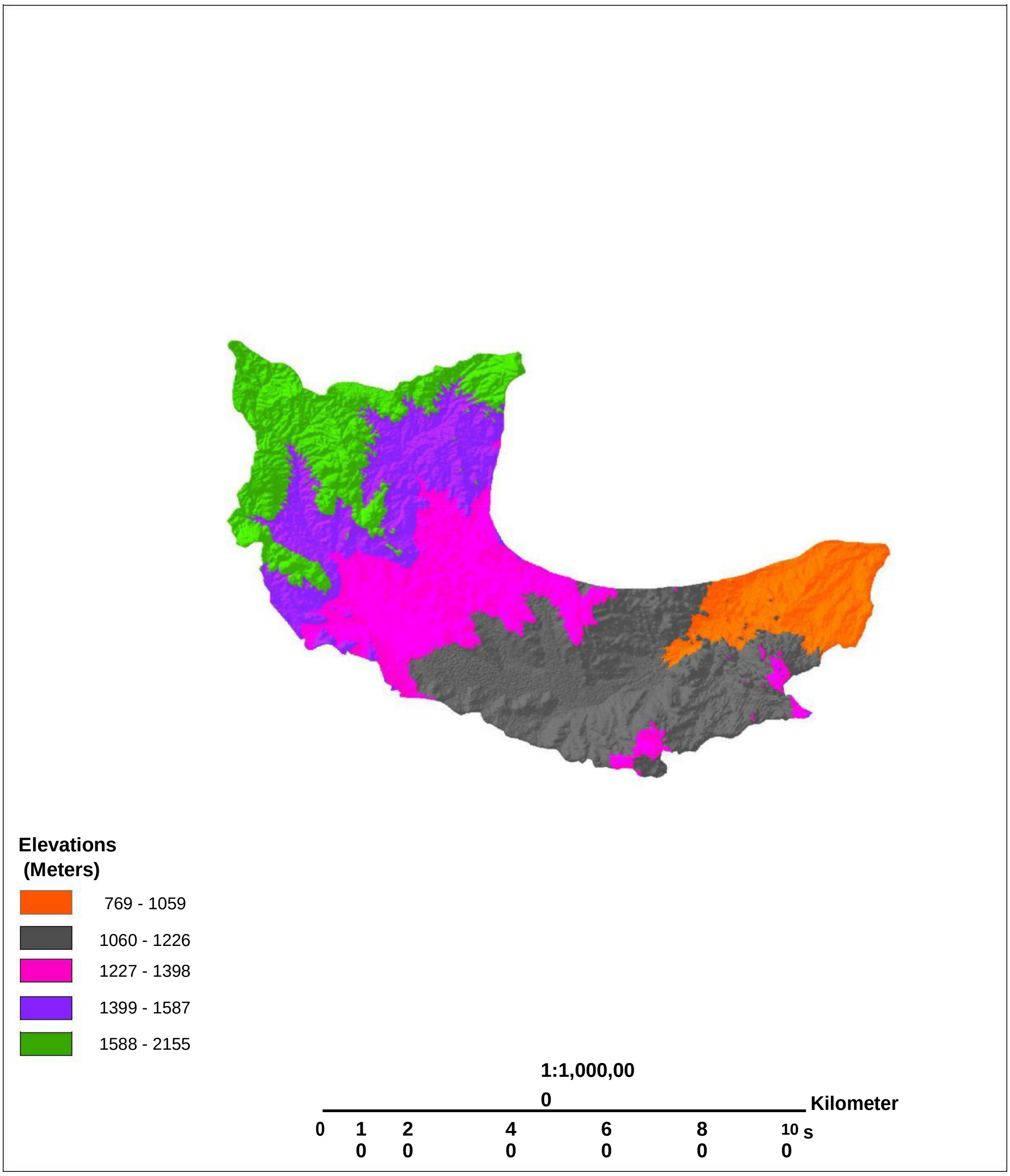

Figure 2. Kiboko DEM

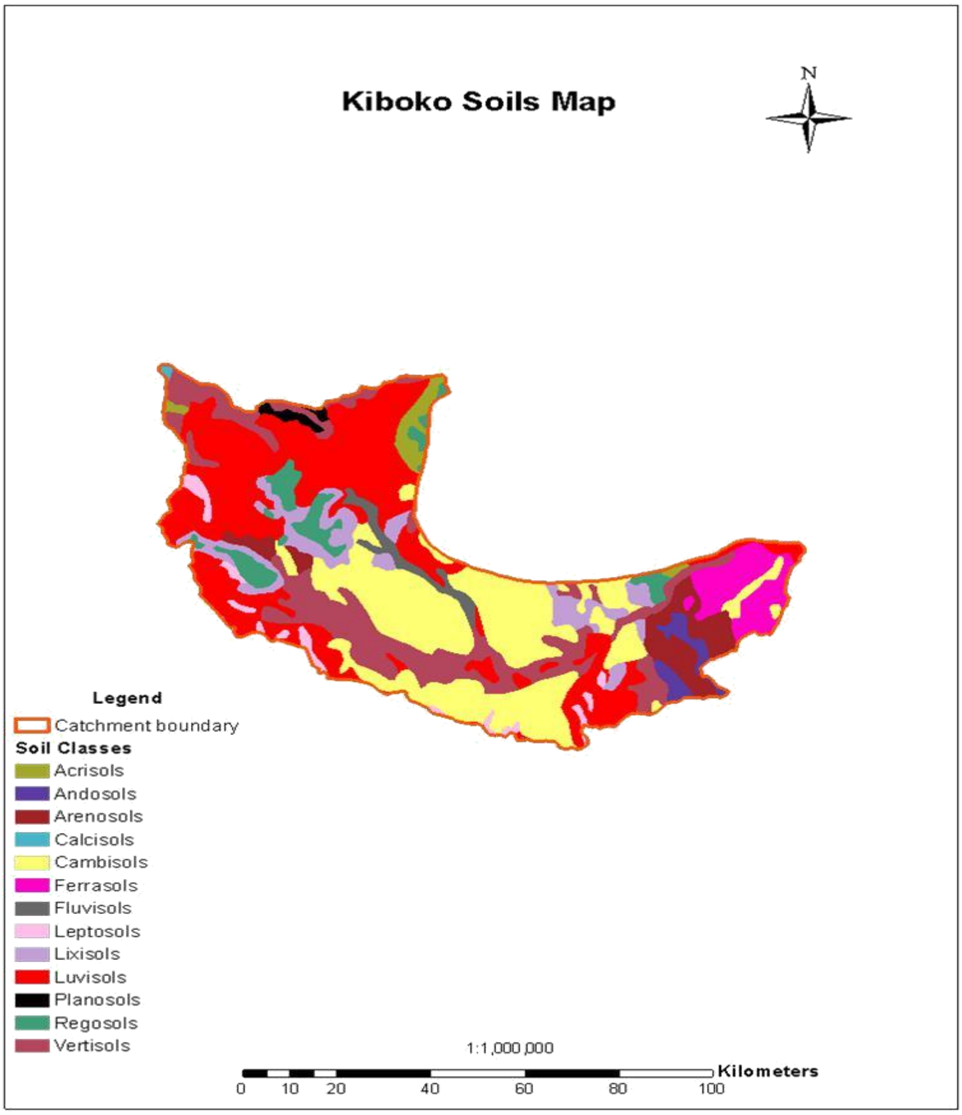

Figure 3. Major Kiboko Soils

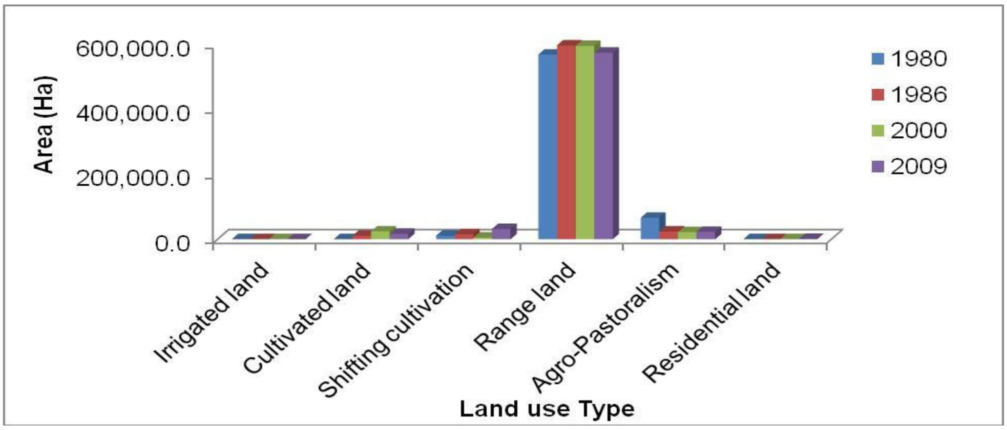

Figure 4. Area under various land use types in Kiboko watershed

RESULTS AND DISCUSSION

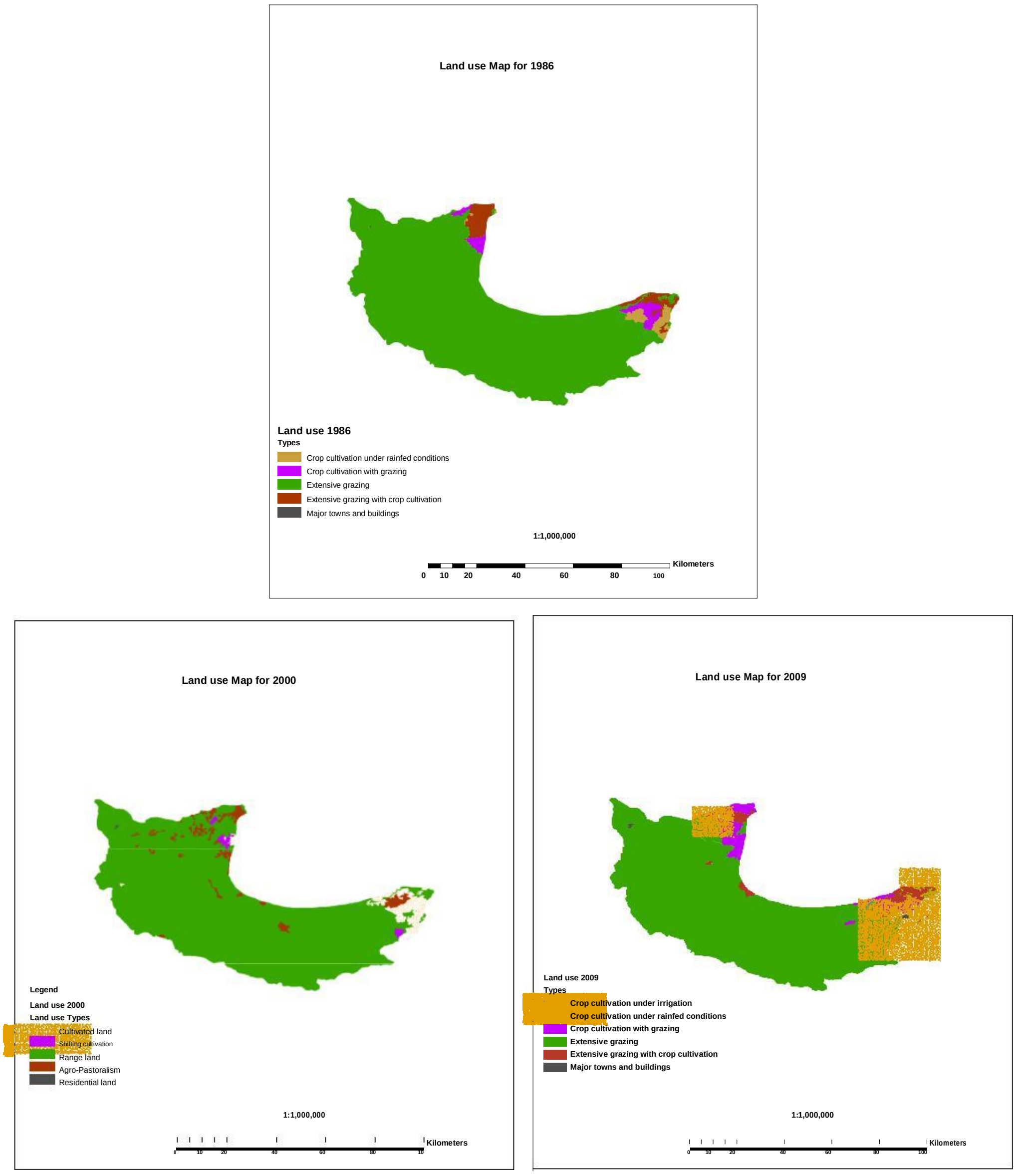

Figure 5. Status of land use maps for the Kiboko watershed from 1980 to 2009

Four land use maps were prepared using ArcGIS for the period 1980, 1986, 2000 and 2009 (Figure 5). The dominant land use type of Kiboko watershed was rangelands (Table 1, Figure 4 and 5), which accounted for about 90% of the entire area (88%, 92%, 92% and 89% for 1980, 1986, 2000 and 2009 respectively). There were two main trends of land use changes during 1980–2009: the increase of conversion of land for crops and residential land. Compared with 1980, cultivated land, shifting cultivation, range land and residential land of 1986 increased by 10,682, 4,430, 27,978 and 63 Ha, respectively over this period; while agro-pastoralism decreased by 42,783 Ha. Comparison of land use change of 1986 and 2000 shows that cultivated land and residential land increased by 13,353 and 128 Ha respectively; while shifting cultivation, rangeland and agro-pastoralism decreased by 10,005, 1,175, and 1,540Ha respectively. In land use of 2000 and 2009; Shifting cultivation, Agro-Pastoralism, Residential land and Irrigated land increased by 26,189Ha, 797Ha, 582Ha and 395Ha respectively, while cultivated and Range land decreased by 7,080Ha and 21,058Ha respectively.

Table 1. Land use status of Kiboko watershed from 1980 to 2009

LAND USE CATEGORIES	1980		1986		2000		2009	
	AREA (Ha)	AREA (%)	AREA (Ha)	AREA (%)	AREA (Ha)	AREA (%)	AREA (Ha)	AREA (%)
Irrigated land	0	0%	0	0%	0.00	0%	395.4	0%
Cultivated land	0	0%	10,682.2	2%	24,034.8	0%	16,955.3	3%
Shifting cultivation	10,783.9	2%	15,214.4	2%	5,209.8	4%	31,398.6	5%
Range land	568,756.5	88%	596,734.9	92%	595,559.6	92%	574,502.0	89%
Agro-Pastoralism	66,205.7	10%	23,423.2	4%	21,883.2	3%	22,679.9	4%
Residential land	0	0%	62.7	0%	191.1	0%	773.1	0%
Total	645,746	100%	646,117	100%	646,878	100%	646,704	100%

Table 2: Land use change of the Kiboko watershed during 1980-2009

Land Use Change Categories	1980/1986		1986/2000		2000/2009	
	AREA (Ha)	AREA (%)	AREA (Ha)	AREA (%)	AREA (Ha)	AREA (%)
Irrigated land	0	0%	0	0%	395.40	0%
Cultivated land	10,682.2	2%	13,352.6	2%	7,079.5	3%
Shifting cultivation	4,430.5	0%	10,004.6	2%	26,188.8	1%
Range land	27,978.4	4%	1,175.3	0%	21,057.6	3%
Agro-Pastoralism	42,782.6	6%	1,540.0	1%	796.8	1%
Residential land	62.7	0%	128.3	0%	582.0	0%

Table 2 lists the main land use conversions. Overall, the land use types of the Kiboko watershed changed little from 2000 to 2009, and only about 5% of the entire watershed underwent type conversions. There were mainly three land use type changes whose areas were less than 1000 Ha [irrigated land (395Ha), Agro-pastoralism (797Ha), and residential (582Ha)]. The changes fell into two groups: one was the mutual conversion between rangeland and agro-pastoralist, the other was the conversion of cultivated land to other land use. Different land use pattern should have different effects on rainfall-runoff relationships. For example, the conversion of shrub-land and woodland to cropland cover would increase runoff, and a decrease in woodland and an increase in construction land would also increase runoff. Plates 1-4 depict effects of land use change on the watershed.

Plates 1-4. Effects of changing land use in Kiboko watershed

CONCLUSION

Kiboko Watershed has in a period of 30 years (1980-2009) undergone a great changes in land use/cover with more land opened up for cultivation at the extent of the natural vegetation cover. The land use of shifting cultivation, cultivated land, range land, residential and irrigated land areas increased by

20,615Ha, 16,955Ha, 5,746Ha, 773Ha, and 395Ha respectively within the period. However, the Agro-Pastoralism land use decreased by 43,526 Ha.

Clearing of natural vegetation to pave way for crop production is mostly occurring on the downstream part of the watershed while rangelands still dominates in the upslope. Generally, it can be concluded that the area under cultivated land for crop production both under rainfed and irrigated conditions and residential land are on increasing trend while that of range land is on a decreasing trend.

ACKNOWLEDGEMENT

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