Land Use/Land Cover Changes in a Disturbed River Watershed Kenya

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Abstract

Drivers of land use change were captured by the use of DPSIR model where Drivers (D) represented human needs, Pressures (P), human activities, State (S), the ecosystem, Impact (I) services from the ecosystem and Response (R), the decisions taken by land users. Land sat MSS and Land sat ETM+ (path 185, row 31) were used in this study. The Land sat ETM+ image (June 1987, May, 2000 and July, 2014) was downloaded from USGS Earth Resources Observation Systems data website. Remote sensing image processing was performed by using ERDAS Imagine 9.1. Two land use/land cover (LULC) classes were established as forest and shrub land. Severe land cover changes was found to have occurred from 1987-2000, where shrub land reduced by -19%, and forestry reduced by -72%. In 2000 – 2014 shrub land reduced by-45%, and forestry reduced by -64%. Forestry and shrub land were found to be consistently reducing.

Keywords: watershed. Land use\land cover change, Landsat imagery, Geographic Information System

Introduction

Land use/Land cover change (LULCC) is continuously changing the Middle part of the River Njoro watershed, thereby threatening sustainability and livelihood systems of the people. Biodiversity is facing widespread competition with humanity as human population increases, resulting in increasing conflict between economic development and the need for biodiversity conservation. These environmental problems are often related to LULC changes. LULCC and human/natural modifications have largely resulted in deforestation, biodiversity loss, global warming and increase of natural disasters like flooding (Fan *et al.*, 2007, Dwivedi, *et al*, 2005). LULCC plays a major role in the study of global Land use/land cover change. Coexistence between local land uses and conditions for environmental, social, and economic sustainability has not been adequately addressed. Land use/land cover change is dynamic. It is mainly driven by natural phenomena and anthropogenic activities. Seto, *et al.*, 2002, has reported that pressure from growing population and increasing socio-economic necessities results in unplanned and uncontrolled changes in LULC. Therefore, available data on LULC changes can provide critical input to decision-making of environmental management and planning the future (Fan, *et al.*, 2010, Prenzel, 2004).

Drivers, pressure, State, Impact and Response (DPSIR) model as a decision making tool, has been applied in numerous research efforts; including Water Resources Management at various scales. It has also been used in a series of international and multidisciplinary research projects as the main analysis tool (Tscherning *et al.*, 2012). The demand for agricultural land, energy, water, food, transport and housing can serve as examples of driving forces (Giupponi, 2002; Kristensen, 2004; Wood and van Halsema, 2008). Pressures consist of the driving forces' consequences on the environment such as the exploitation of resources (land, water, minerals, and fuels), pollution and the production of waste or noise (Wood and van Halsema, 2008). As a result of pressures, the 'state' of the environment is affected; that is, the quality of the various natural resources (air, water, and soil) in relation to the functions that these resources fulfill. The 'state of the environment' is thus the combination of the physical, chemical and biological conditions. The support of human and non-human life as well as the depletion of resources can serve as pertinent examples (Kristensen, 2004). Changes in the state may have an impact on human health, ecosystems, biodiversity, amenity value and financial value. Impact may be expressed in terms of the level of environmental harm and finally, the responses demonstrate the social efforts to solve the problems identified by the assessed impacts, e.g. policy measures, and planning actions (EEA, 1999; Giupponi, 2002; Kristensen, 2004; Wood and van Halsema, 2008).

Remote sensing and Geographical Information Systems (GIS) as a resource management tool is powerful to derive accurate and timely information on the spatial distribution of land use/land cover changes over large areas (Guerschman, *et al*., 2003, Rogana and Chen, 2004, Zsuzsanna, *et al*., 2005). GIS provides a flexible environment for collecting, storing, displaying and analyzing digital data necessary for change detection (Yomralıoğlu, *et al*., 2000, Demers, 2005, Wu *et al.,* 2006). The aim of land cover change detection process is to recognize LULCC on digital images that change features of interest between two or more dates (Muttitanon and Tiıpathi, 2005).This change in land use has exposed the land to various pressures resulting from poor management, low cost technologies for soil fertility management, continued use of inappropriate technologies and intensive cultivation. Therefore, there is a need to understand how land use changes had affected the environmental sustainability of the area.

1. Study Area

The area of study covers about 8,170 ha and lies between latitudes 0º 15´ S and 0º 25´ S and longitudes of 35º 50´ E and 36º 00´ E (Figure 1). The whole watershed has a population of about three hundred thousand (300,000) people with more than three thousand (3000) individual farm holding units (Baldyga, *et al.,* 2003). However, according to Kenya National Bureau of Statistics, Njoro Sub County registered a population of 23,551 people having grown by 3% from a population of 22, 845 people in 1999 (KNBS, 2009). Based on the same growth rate, the watershed population may have also grown to 309, 000 people with may be 3100 households. Due to the heavy settlement in the middle part of the watershed, it is estimated to be home to about 2000 farm holding units in an area of more than 8,000 ha with slopes ranging from < 2 to > 18 % and soils that are predominantly volcanic clay loam except near the lake where silt clay is found (Mainuri and Owino, 2013).

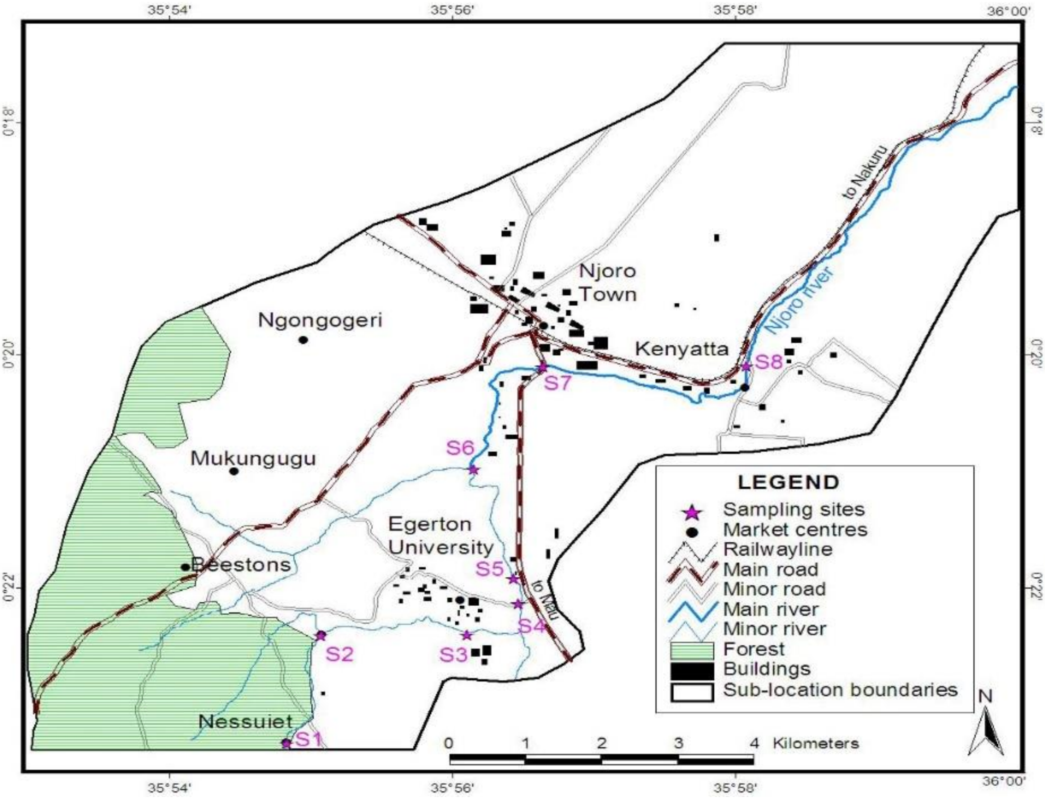

Figure 1: Middle River Njoro Watershed (Source: Mainuri and Owino, 2014)

2. Methods

A baseline survey at household-level encompassing socio-economic changes and impacts of land use activities in the middle part of the River Njoro Watershed was established. Additionally, information on factors influencing land use decisions, productivity factors and change in economic activities were sought through use of a questionnaire. The middle part of the River Njoro Watershed household survey was to target an area of approximately 8000ha.The Landsat scenes were selected (1987, 2000 and 2014) for this study. These dates captured the major excision and settlement changes that have taken place in the watershed. Efforts were made to acquire imagery that corresponds with major land use/land cover changes within this period.

The study utilized 200 questionnaires which were administered to homesteads that were initially identified at random on both sides of the river. The questionnaires were subjected to scrutiny for completeness and consistency in question answering and the way they addressed the various issues intended to be captured. The questionnaires were sorted out and entered into the SPSS (version 20) work sheet. With the descriptive and categorical nature of most of the questions, simple descriptive analysis was done using SPSS and inferential statistics performed based on the results.

2.1 Image classification

Land sat MSS and Land sat ETM+ (path 185, row 31) were used in this study. The Land sat ETM+ images (June 1987, May, 2000 and July, 2014) were downloaded from USGS Earth Resources Observation Systems data. The dates of both images were chosen to be as closely as possible in the same vegetation season. All visible and infrared bands were included in the analysis. Remote sensing image processing was performed using ERDAS Imagine 9.1.Five LULC classes were established as commercial farms, forest, settlement, subsistence farms, and shrub land. Three dated Land sat images (1987, 2000, and 2014) were compared using supervised classification technique. In the supervised classification technique, three images with different dates were independently classified. A Supervised classification method was carried out using training areas. Maximum Likelihood Algorithm was employed to detect the land cover types in ERDAS Imagine 9.1.

3. Results

3.1 Nature and status of Land Use/ Cover during acquisition time

The study established that most of the land was under cultivation when the current owners acquired it, as the majority (31.7%) of the responses portrays it. This was closely followed by grass cover which formed 26.6% of the total responses, with 19% reporting that the land area was under indigenous trees when they initially moved in, while a 15.4% response exhibited presence of exotic trees. However, only 7.3% of the total responses reported the presence of soil and water conservation structures on the land during initial settlement period (Table 1).

Table 1: Nature/ state and extent of Land cover during acquisition by current owners

Land Use/ Cover	Responses on Land use		Percent of Cases (interviewed)
	N (Number of Respondents Interviewed)	Percent (observed Land use change)	
Presence of soil and water conservation structures	24	7.3%	12.9%
Under cropping	105	31.7%	56.5%
Under grass cover	88	26.6%	47.3%
Under indigenous trees	63	19.0%	33.9%
Under exotic trees	51	15.4%	27.4%
Total	331	100.0%	178.0%

3.2 Land use activities and factors influencing decisions

An interview was carried out on some key informants concerning the land use activities. They reported that the main environmental impacts were a general increase in agricultural activities on riparian zones. The main economic activity creating impacts to the ecosystem that was reported by these people was usually farming which resulted in the reduction of natural vegetation. However, the state of the ecosystem has remained a bit stable due to agro forestry that has contributed to planted forest which is thriving in some parts of the ecosystem. The response from those interviewed indicated that 88 per cent of those interviewed were farmers, 3 percent were business persons, 3 percent masons, and 3 percent crafts men and 3 percent teachers. Respondents' level of education refers to the actual number of years spent in school. The interview showed that 50 percent of the respondents had obtained up to primary education, while 20% percent have not obtained any formal education. A lower proportion (33%) had obtained secondary and post secondary level of education. Generally, 70 percent of the respondents had primary level education and below. The finding indicates that most of the respondents in the middle part of the river Njoro watershed had low formal education and this may have affected the way in which they responded to new information on resource conservation and how they also received innovative ideas.

The respondents were interviewed on the changes in natural vegetation. A huge portion of the respondents (93%) have observed massive land use changes taking place with 7% not feeling that there has been any noticeable change in land use. This possibly could be that they have recently settled in the area and since they settled there has been no change. The pressures exerted by the society through deforestation may have led to unintentional or intentional changes in the state of the ecosystem. As a result of no proper land ownership, most people are shy to invest in long term development activities and majorities are sluggish or unable to take any resource conservation measures. Assessment of driving forces behind land use change was done to capture past patterns and also be able to forecast future patterns. Driving forces on land use included most of the factors that influenced human activity that exert pressure on the ecosystem, including population increase, poverty, land tenure and markets. Also other underlying factors that drive actions like food preference demand for specific products, financial incentives and environmental state indicators such as soil quality, terrain and moisture availability played a great role in affecting the natural vegetation as shown in Table 2.

Table 2: Change detection

Class Type	1987 Area in Hectares	2000 Area in Hectares	2014 Area in Hectares	Percent change in area (2000-1987)	Percent change in area (2014-2000)
Forest	1460.898	405.351	145.712	(-1055.55)- 72%.	(-259.64) -64%
Shrub land	849.281	687.820	373.150	(-161.46) - 19%,	(-341.67) -45%

Increasing land use/cover changes were observed in the middle part of the river Njoro watershed ecosystem over the last twenty seven (27) years. These changes resulted from a number of factors, but mainly related to habitat loss due to various human activities. Information about changing patterns of land use/cover through time and the factors influencing such changes have been captured in the change detection maps shown in Figure 2, 3 and 4 below.

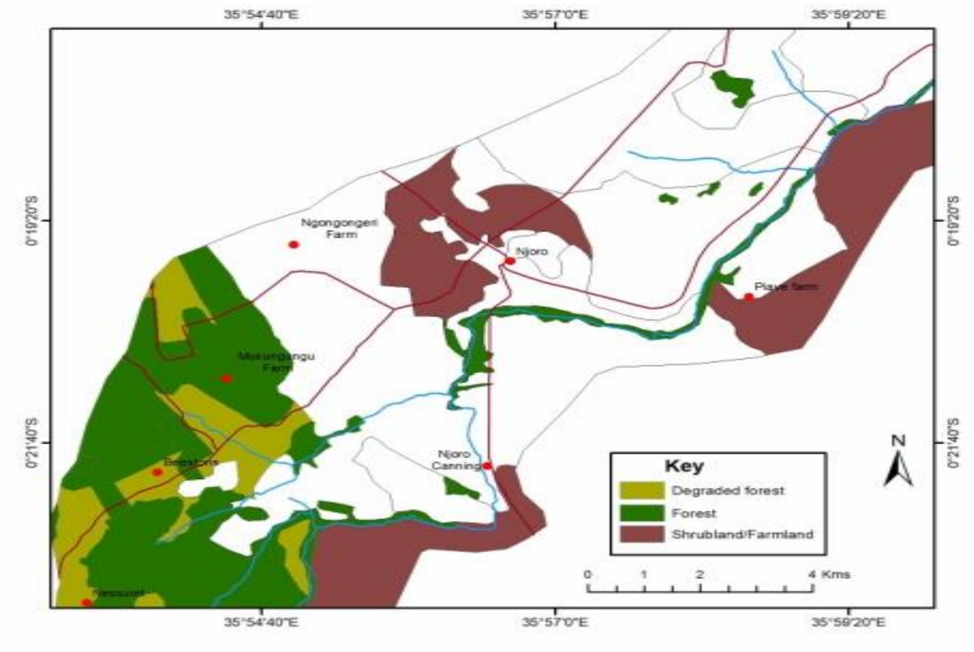

Figure 2: Forests and Shrub Lands cover in 1987

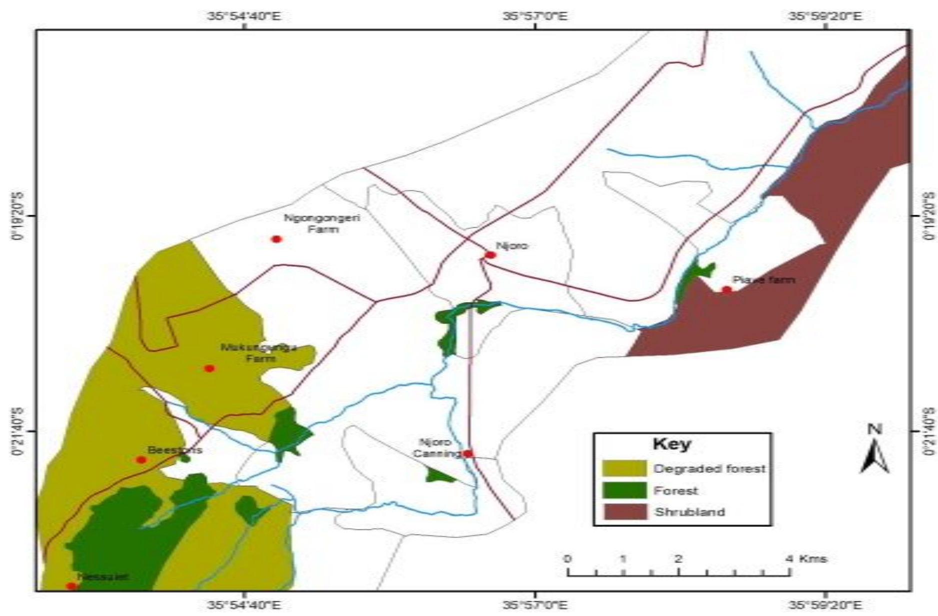

Figure 3: Reduction of Forests and Shrub Lands in the year 2000

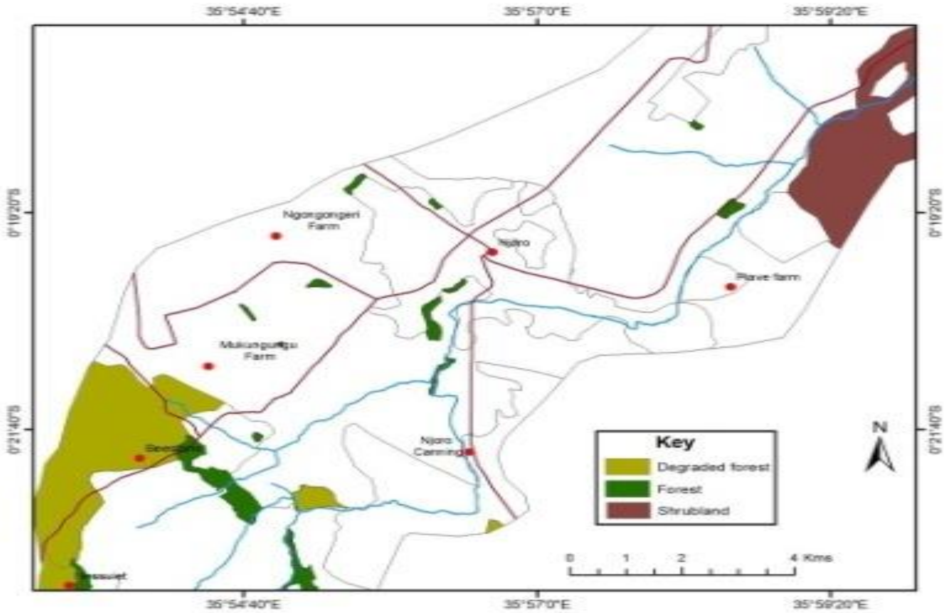

Figure 4: Reduction of Forests and Shrub Lands in the year 20014

3.3 Natural Vegetation Cover

From the study, it is evident that natural vegetation which was indicated by forest and shrub land (Table 3) has reduced over the period the respondents have resided in the area. The results from image processing and analysis for the years 1987, 2000 and 2014 portray a general reduction in both forests and shrub lands within the study area. We can therefore say that deforestation has been witnessed in the study area for the last two decades due to land use patterns.

Table 3 Respondents' view on Natural Vegetation

Year	Forest Area(ha)	Shrub land Area (ha)	Natural Vegetation Change	Frequency (Number interviewed)	Percent of respondents interviewed
1987	1460.898	849.281	Decrease	32	20.6
2000	405.351	687.820	Decrease	123	79.4
2014	145.712	373.150	Total	155	100

3.4 Reasons for Reduction in Natural Vegetation

Several activities and their impact on reducing natural vegetation were identified during the study. From Table 4, cultivation stood out to be the major driving force that led to the reduction in natural vegetation cover in these areas as reported from the respondents. This constituted 33% of the total responses. Other activities included charcoal burning (11.2%), infrastructural development (10.4%) and grazing (9.9% and commercial timber production (4.7%). Collectively, these have led to deforestation in the area under study.

Table 4: Responses for change in natural vegetation

Reasons for change	Responses on Land cover change		Percent of Cases
	N	Percent(observed)	
Commercial timber production	18	4.7%	11.1%
Cultivation	127	33.0%	78.4%
Infrastructural development	40	10.4%	24.7%
Charcoal burning/ firewood	43	11.2%	26.5%
Grazing	38	9.9%	23.5%

4. Discussions and Conclusions

In order to determine the current land use and factors that influence land use decisions in the middle part of the River Njoro watershed the study sought to established the kind of land use before the occupation of the current inhabitants. It was found that 32 % of the land was under cultivation when the current owners acquired it as confirmed by the interviewee. 27% of the respondents indicated that they occupied land that was under grass cover with 19% reporting that the land area was under indigenous trees when they initially moved in, while a 15% response exhibited presence of exotic trees. Driving forces on land use included most of the factors that influenced human activity that exert pressure on the ecosystem, including population increase, poverty, land tenure and markets.

Alongside determining the land use and factors influencing land use decisions, the study also looked at land use/land cover changes that were as a result of land use decisions that the people made. It was noted that there were increasing land use/cover changes observed in the middle part of the river Njoro watershed over the period of study. These changes resulted from a number of factors that included increase in population, change in lifestyle and the need to provide food for the increasing numbers of people.. Several activities and their impact on reducing natural vegetation were identified during the study with cultivation being the major driving forces that has led to the reduction in natural vegetation cover in these areas constituting 33% of the total responses. Other activities that contributed to land use/land cover change included charcoal burning, infrastructural development and grazing and commercial timber production. Collectively, these have led to deforestation in the area under study.

Land degradation by overgrazing and intensive agriculture on marginal lands is a major driver of land cover loss in the middle part of the river Njoro watershed. In this rapidly industrializing area with dense populations, demand for land for industry and residential use is driving the transformation of some of the most productive agricultural land out of production in the watershed. Policy efforts to avoid this loss of production are there but, their effectiveness in the face of economic demand is often limited. The effectiveness of these efforts and other national efforts to reduce the negative impacts of LULCC remain to be seen. The need for greater efforts and new methods to monitor and mediate the negative consequences of LULCC remains acute and we have to sustain current and future human populations under desirable conditions. This can be realized by putting in place policies like reafforesttion of natural forests, mandatory planting of trees in homestead, controlled tree harvesting and restricting encroachment into the forests.

Conclusion

The factors driving land use decisions in the middle part of the River Njoro watershed include demographic and economic developments in the watershed community, and the corresponding changes in lifestyles, overall levels of consumption and production patterns. These drivers have exerted pressure to the ecosystem in form of waste disposal, over cultivation, overgrazing and deforestation. These pressures have caused negative changes to the watershed which have caused heavy impacts mainly through removal of natural vegetation. The removal of natural vegetation (LULCC) in the middle part of the River Njoro watershed has resulted in the decrease of the forest area by 1314 ha and shrub land by 475 ha in the last 27 years. The integration of remote sensing and GIS was found to be effective in monitoring and analyzing land cover patterns and also in evaluating impacts of land use change for future land development projects by the residents of study areas.

The residents are therefore recommended to develop responses to rehabilitate the degraded environment through re-afforestation, soil and water conservation and reduction of land use/land cover change (LULCC) in order to mitigate the negative outcomes of the ecosystem changes.

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