International Journal of Agriculture, Environment and Bioresearch

Vol. 2, No. 05; 2017

ISSN: 2456-8643

ASSESSMENT AND PROJECTION OF LAND USE AND LAND COVER CHANGE IN NGURUMAN SUB-CATCHMENT, KAJIADO COUNTY

Malaki Philista Adhiambo[1], Geoffrey Kironchi[2], Stephen Mureithi[2] and Vincent Kathumo[2]

1Department of Zoology, National Museums of Kenya, Kenya.
2Department of Land Resources Management and Agricultural Technology, College of Agriculture and Veterinary Sciences,. P.O BOX 29053 (00625), University of Nairobi
Tel: 020631340, 020631281 Ext. 27021; Fax: 631225

ABSTRACT

Nguruman sub-catchment has undergone rapid land use and land cover changes (LULCC) in the past decades. Statement It is not known to what extend this changes could impact on the socio-ecological environment. The current study employed Geographic Information System (GIS) and LANDSAT images to determine the dynamics and underlying drivers of LULCC in the sub-catchment. LANDSAT Images for the period 1994, 2004 and 2014 were purposely acquired and supervised classification performed using ENVI 4.7 software. The classification resulted into seven LULCC classes identified as Cropland, Forestland, Open grassland, Open Water, Bare land, Swamp and Wooded grassland. The area under each LULCC was determined and subjected to a change detection analysis using ArcGIS 9.3 for the periods 1994-2004, 2004-2014 and 1994-2014. Cropland and Open water showed a significant overall increase ($P<0.05$) of 181.5% and 91.93% respectively from 1994 to 2014. Bare land reduced significantly by 35% in the same period. Areas occupied by Forestland, Open grasslands and Swamps increased by 19.45%, 11.82% and 14.6% respectively from 1994-2014, though this was not significant ($P>0.05$). There was a non-significant ($P>0.05$) reduction in Wooded grasslands between 1994 and 2014 by of 6.30%. Regression analysis was further performed to determine 25 year projection for the various land use categories revealed that cropland, bare land and wooded grassland will expand by the year 2040. While there will be reductions in forestland, swamps and open water in the same period. The consequences are expected to have negative impacts on hydrological functions of the catchment with increase in runoff and sedimentation in the streams. Sustainable land use measures are needed to address the challenges of prevailing land use practices.

Keywords: Land use change, Nguruman sub-catchment, GIS, LANDSAT images, ENVI, change detection

Introduction

Land-use refers to the specific utilisation allocated to land based on various natural characteristics while land-cover describes the vegetation attributes of the land (Ifeka and

Akinbobola 2015). Land use and land cover change (LULCC) are a result from natural and anthropogenic processes. The latter is driven by the demand for essential goods and services to satisfy livelihoods (MEA 2005). The impacts range from conversion of natural forest to cropland due to demand for food, fibre and settlement. Land use and land cover change that leads to removal of natural vegetation is also associated with land degradation (Pares-Ramos *et al.* 2008 , Wanjiku *et al.*, 2015) causing reduced land productivity (Gathaara 2010, Tsegaye *et al.*, 2010).

Cropland expansion has been identified as one of the key drivers of land use change. Syombua 2013 observed that irrigated agriculture continued to expand replacing forests by 1987 with the most drastic expansion occurred between 2001 and 2011 expansion by 54.54 and 17.14% respectively. Haruna *et al.*, 2014 observed an overall 80% expansion of deforestation in the upper part of the Mount Kenya Forest catchment. Most of this deforestation was understood to have taken place in the 1980s and 1990s with 2.5% forest depletion between 1984 and 1995 driven by cropland expansion. A study conducted by , Mwavu and Wirkowski, 2008 in Bundogo forest reserve in Uganda showed that sugarcane cultivation increased over 17-fold, from 690 ha in 1988 to 12729 ha in 2002, with a concomitant loss of about 4680 ha (8·2 per cent) of forest/woodland. In Lake Bunyonyi, in western Uganda over 96 and 81% of the gain and loss, respectively, in tropical highland forests were from small-scale farmland (Kizza et al 2017). In South Western Ethiopia conversion of natural vegetation to pave way for farming occurred at a rate of 0.7% on an annual basis (Dessie and Christiansson,2008).). Over that time period, the area of rainfed agriculture expanded 177 percent and that of irrigated agriculture 45.2 percent in Loitoktok (Campbell *et al.*, 2003). The principal changes were associated with the availability of water for crop production. Kathumo 2011 in a study in Gucha River catchment also showed that more forestland was being cleared for agriculture and settlement. Forest cover decreased by 62.94 and 68.49%, agricultural land increased by 30.36 and 7.53% and residential area increased by 7.35 and 32.89% of the original area for the period between 1976-1993 and 1993-2010 respectively. Ayuyo and Sweta 2014 showed that changes in land use and land cover in 22 blocks study in Mau forest complex resulted in the reduction of forest cover and expansion of farming and settlement by 7% between 1983 and 2000.

Human population increase has also been identified as key factor underlying land use and land cover change (Dessie and Christiansson 2008, Ningal *et al.*, 2008, Paré*set al.*, 2008, Kamusoko 2007, Jorgenson and Burns 2007, Enfors and Gordon 2007, Reij *et al.* 2005, Zeleke and Hurni, 2001). This population is contributed both by natives and immigrants. The later population is associated with increased pressure (Okello and Ngigi 2012) on the land, since there presence is associated with activities that cause more impact on the new environment. In most cases, immigrant populations in arid and semi-arid landscapes are associated with changing livelihoods as a way of adapting to the new environmental shocks (Sambalino 2012). Farming as a means of livelihood diversification and adaptation mechanism in dry environments is always the key activity manly by exploiting favorable areas along riparian areas (Okello and Ngigi 2012, Sambalino 2012). Infrastructure development and proximity to ready markets (Baaru 2011) and good road networks (Syombua 2013) are other key factors associated with expansion of cropland

The current intensity and extent of land use and land cover change is far greater than ever in history impacting highly on ecosystems and environmental processes at different spatial scales (Ellis and Pontius 2007). These changes have led to global environmental concerns including climate change, biodiversity loss, impairment of nutrient and hydrological cycles, biological invasions and pollution of water, soils and air (Tilman and Lehman, 2001, Legesse *et al.*, 2003, Steffen *et al.*, 2004, Templer *et al*., 2005 IPCC, 2007). These therefore necessitate the need to focus on monitoring and prioritizing research and policy issues that ensure sustainable production of essential goods and services (Ellis and Pontius, 2007). Both qualitative and quantitative spatial data on land use and land cover are essential for planners, decision makers and land resource managers (Lambin *et al.*, 2003). Natural and anthropogenic changes can be determined using remotely sensed data (Mubea and Menz, 2012).

Data from Earth sensing satellites has become vital in mapping the Earth's features and infrastructures, managing natural resources and studying environmental change. Traditionally, methods of studying LULCC depended on survey data, aerial photographs and fieldwork to obtain data. These approaches proved to be expensive and time-inefficient. Several reports have proposed the use of remote sensing techniques aided by GIS for monitoring dynamics and impacts of LULCC of watershed environment (Baldyga *et al*., 2008, Saran *et al*., 2009). Remote sensing allows gathering data on regional LULCC patterns (Treitz and Rogan, 2004, Rogan and Chen, 2004). Data obtained from remote sensing is essential for the characterization of land cover, environmental monitoring and analysis of the influence on anthropogenic activities on natural resource base (Turner *et al*., 2003, Lu *et al*., 2004). Remote sensing provides objective information of human utilization of the landscape in situations of rapid and often unrecorded land use change (Ermias, 2006). This tool thus provides an accurate temporal and spatial evaluation of status of the world's natural resources (Ioannis and Meliadis. 2011).

Materials and Methods

Study Area

The Study area is located in South-western of Kenya at the border with Tanzania between latitude 1^o 40.00'S and 2^o 10.00' S and longitude 36^o 30.0' E and 36^o 30.0' E), about70 km southeast of Nairobi and 100 km Northwest of Arusha, Tanzania (Figure 1). The area lies within

ISSN: 2456-8643

the Ewaso Ng'iro south river basin. The Nguruman sub-catchment rises steeply in a series of stepped, rocky faults from the flood-plain of the Southern Ewaso Ng'iro River on the valley floor at approximately 900 m to 2,300 m above sea level on the escarpment crest.

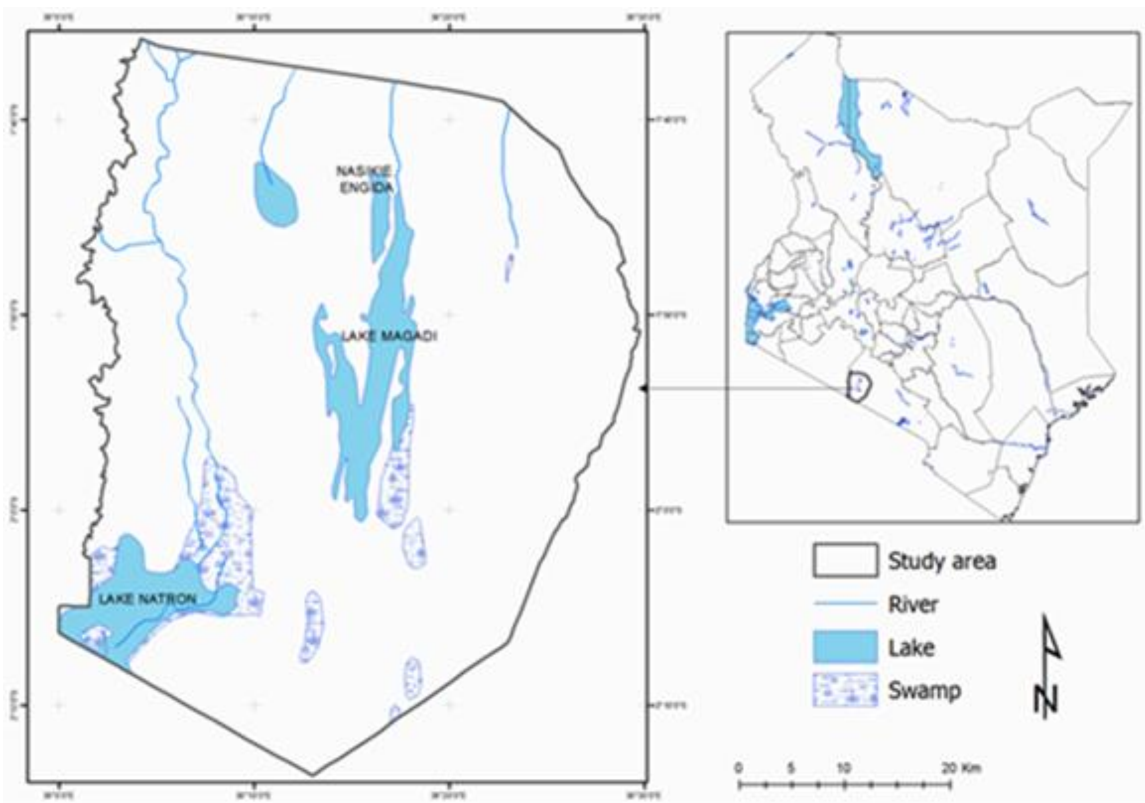


Figure 1: Map of Study Area

Data Acquisition

Selection of appropriate satellite imagery was undertaken through image data processing. This involved analysis of LANDSAT TM and ETM images covering the area of study for the periods 1994, 2004 and 2014 sourced from United States Geological Survey website. The LANDSAT imageries used covered period of 10 years intervals. This interval is believed to be reasonable enough to give substantial changes in land use and land cover. Data from ground truthing was used for supervised classification.

Image classification and change detection

The images were later pre-processed by registration and sub setting using ground control points (GCPS) (Mwavu and Witkowski 2008). This was followed by undertaking image classification starting with unsupervised classification by comparing individual pixel to each discrete cluster to see which one it is closest to in order to derive the available classes then followed by supervised classification using multi-temporal LANDSAT data processing using ENVI 4.7 software. The classification resulted into seven (7) land use and land cover categories (Table 3.4.1) under confirmation from ground truthing data. Land use and cover change detection analysis was done for each cover class on ArcGIS (ESRI, 2009), to determine the area covered by each land use cover type and change detection.

A land-use and land cover change detection analysis was done by involving the images of (1994, 2004) and (2004, 2014) using confusion matrix. Change detection was done for the classified land use and land cover types by comparing two images of different time periods (1994 to 2004, 2004 to 2014 images and 1994 to 2014). By comparing two classified sets of data, the matrix operation was able to show all the changes from one class to another. Chi-square goodness of fit test was then used to test significance in land use cover changes. Logistic regression was then performed to project (25 years) land use and land cover scenario for the different classes.

The results of regression are presented in Figures 3-7.

Table 1. Descriptions of land use/cover classes

Land use/Cover	**Descriptions**
Cropland	Areas covered by growing crops , ploughed fields and horticultural farms
Forestland	Areas predominantly covered by tree (>5m high) with closed canopies (>40%
Open Grassland	Areas dominated by grasses(0-0.2m) and herbs (0-0.2m)
Open Water	Areas covered by open waters, rivers and lake
Bareland	Areas completely non-vegetated (bare) areas, rocky or are covered with very
Swamp	Areas covered by vegetated wetlands
Wooded Grassland	Areas characterized by a high percentage of shrub cover (2-5m high)

Results and Discussions

Land use and land cover change

Areas occupied by different land use and land cover types from 1994 to 2014 showed variation (Table 2). Wooded grassland comprised the main land cover type in the sub-catchment (62.9%) followed by open grasslands (23.4%). The vegetated wetland (swamps) had the least coverage and occupied 0.44% of the total sub-catchment. LULCC maps for Nguruman sub-catchment for the year 1994, 2004 and 2014 (Figures 3a, b and c) were generated following the LANDSAT image analysis and classification,

The results indicate that the Nguruman sub-catchment has undergone rapid land use land cover changes in the last 20 years (Table 2). Significant land conversions occurred in Cropland ($p<0.01$), Bare land ($p<0.01$) and areas occupied by Open water ($p<0.01$) (Table 3). Cropland expanded by 108.5% (1994-2004) and again by 35.14% (2004 and 2014). In overall expansion Cropland expanded significantly ($p<0.01$) by 181% from 1994 to 2014. Open water expanded by 106.83% (1994 -2004) and declined by 7.2% (2004-2014). Generally there was a significant ($p<0.01$) expansion of 91.93% from 1994 to 2014 for the Open water (Table 3). However, wood grasslands declined by 6.30% though this was not significant ($p>0.05$). Bareland declined throughout the period of investigation declining initially by 16.47% (1994-2004), then by 23.06% (2004-2014), with an overall significant ($p<0.01$) decline of 35.73 % from 1994 to 2014.Changes in forestland, open grasslands and swamps were not significant ($p>0.05$). Forestland showed moderate expansions of 11.5% (1994 -2004) and 7.1% (2004 and 2014). However, in overall, forestland expanded by 19.5% from 1994 to 2014. Grasslands on the other hand increased by 3.4% (1994 -2004) and later by 11.8% (2004 and 2014) with overall expansion of 15.6% between 1994 and 2014. The change in area occupied by swamps showed fluctuations with an expansion of 13.8% (1994-2004) and a slight increase of 0.7% (2004-2014) with an overall increase of 14.6% between 1994 and 2014.

Land use and land cover changes widely impact o on aquatic ecosystems status within watersheds (Nelson *et al.*, 2009). Human activities have been identified as the important factor that determine the impact of land use and land cover changes on the water bodies (Lambin *et al.*, 2003). On a catchment scale, land uses associated with human presence can significantly alter natural hydrological processes such as runoff and ground water recharge. This study has identified expansion of cropland as main driver of the land use and land cover changes in Nguruman sub-catchment. In Figure 2 showing land uses changes from 1994 to 2014, the expansion in cropland is mainly directed along the riparian areas where River Ewaso ng'iro begins running north to south on the western sections of the study area. This area also coincides with areas where bare land has declined. This implies bare areas adjacent to riparian land provides opportunities for cropland expansion. Similar observations were reported in other studies e.g. Kundu *et al.,* 2008 employed remotely sensed data and ground survey methods to evaluate LULCC in Mau Forest for a period of about 40 years. The results showed agricultural expansion at the expense of forestland. High- resolution aerial surveys of selected forests in the Aberdares, Mt. Kenya, Mt. Elgon, and the Mau complex revealed that deforestation and general degradation was taking place significantly due to unplanned expansion in agricultural land (Ayuyo and Sweta 2014, Baldyga *et al*., 2008). Similar results have also been reported by Haruna *et al*. (2014), Singh and Khanduri, (2011) where natural vegetation has been converted to cropland. Such trends are also consistent with studies conducted by Kathumo *et al*., 2015, Kathumo 2011, Dessie and Christiansson, 2008; Ningal *et al.*, 2008; Parés-Ramos *et al.*, 2008; Enfors and Gordon 2007,Kamusoko, 2007; Reij *et al*. 2005, Zeleke&Hurni, 2001,). Further expansion of cropland could be attributed to increasing population in the area (Sambalino 2012, Okello and Ngigi 2012) and ready markets for horticultural products both in Kenya and Tanzania from the sub-catchment (Baaru 2011). Syombua 2013, in her study showed an expansion of cropland in Amboseli due to good road networks and markets. Similar results were observed in Budongo forest where forests were being converted to agriculture (Mwavu and Wirkowski, 2008). Kathumo 2011 in a study in Gucha River catchment also showed that more forestland was being cleared for Agriculture and settlement. In Mau forest complex changes in land use and land cover resulted in clearing of forest for farming and settlement (Ayuyo and Sweta 2014).

Open water which included areas occupied by rivers lakes in the sub-catchment increased between 1994 and 2014. The greatest expansion was recorded between 1994 and 2004. This period coincided with the greatest expansion in cropland. Crop farming in the area is mainly supported by irrigation with water abstracted from River Ewaso Ng'iro. This result indicates the linkage between water balance and land use and land cover change resulting from expansion in cropland. The expansion in cropland is likely to have affected the hydrology and water balance of the sub-catchment from un-sustainable irrigation practices. Expansion of cropland goes hand in hand with reduction in riparian vegetation cover. Studies indicate that when more land in riparian area is cleared the volume of river runoff is expected to increase due to the reduction of water being intercepted in the catchment thus contributing to increase in acreage occupied by open water. The natural vegetation protects the soil against the impacts of rainfall and it is a source of organic matter to the soil. These factors improve infiltration and enhance the recharging of groundwater reservoirs. When vegetation cover is displaced, infiltration capacity is decreased resulting in surface runoff, which will carry sediments and nutrients into rivers (Zuazo

ISSN: 2456-8643

and Pleguezuelo, 2008).Reducing forest cover is expected to reduce transpiration demand, which might be expected to increase the amount of water in the watershed to sustain dry season flows. Further soil degradation from degraded landscapes could counteract this effect by reducing the water-holding and infiltration capacity of the soil (Bruijnzeel 2004). Surface albedo increases when forestland is converted to cropland causing a reduction in the net surface radiation. The uniform and smoother surface caused by shorter agricultural crops lead to a decrease in surface roughness, which is the primary factor that determines the aerodynamic exchange between the land surface and the lower atmosphere (Otieno and Anyah 2012).

Bare land declined throughout the period of investigation with an overall decline of 35.73 % from 1994 to 2014. Similarly, wooded grassland recorded declines throughout the period of investigation by 6.30% between 1994 and 2014. Most of the land was left bare as a result of degradation from previously abandoned cultivated land. These areas mostly occurred to the south of the study area where environmental conditions could not sustain farming forcing land owners to abandon the activity (Sambalino 2012). These areas have no vegetation and regeneration rates are slow due to harsh climatic conditions. Removal of natural vegetation, intensive cultivation on these fragile lands and overgrazing without effective conservation measures are the probable cause of increase in bare land. Wanjiku *et al* 2015 made similar observations .Gathaara, (2010) and Tsegaye *et al*. (2010) observed that farmers abandoning degraded land when they were no longer productive. The southern part of the study area is more suited for ranching as opposed to farming whether by irrigation of rain fed. Most of this land when left bare is further exposed to agents of soil erosion that ends up in increasing sediments to the streams. The determination of the potential of land for allocation of land uses is critical for both ecosystem and sustaining livelihoods in the study area.

Table 2: Land use Land cover Changes in Nguruman Catchment

Land use category	1994		2004		2014		Magnitude(% Change)		
	Area (Km^2)	% Area	Area (Km^2)	% Area	Area (Km^2)	% Area	1994-2004	2004-2014	1994-2014
Cropland	24.90	0.93	51.92	1.93	70.16	2.61	**108.46**	**35.14**	**181.71**
Forestland	86.17	3.20	96.11	3.57	102.93	3.83	**11.53**	**7.10**	**19.45**
Open grassland	619.63	23.04	640.44	23.81	716.16	26.63	**3.36**	**11.82**	**15.58**
Open water	33.75	1.25	69.80	2.60	64.77	2.41	**106.83**	**-7.20**	**91.93**
Bare land	240.60	8.95	200.97	7.47	154.64	5.75	**--16.47**	**-23.06**	**-35.73**
Vegetated wetland	11.82	0.44	13.45	0.50	13.54	0.50	**13.81**	**0.69**	**14.60**
Wooded grassland	1672.55	62.9	1616.73	60.11	1567.21	58.27	**-3.34**	**-3.06**	**-6.30**

Table 3: Chi-Square goodness of fit test for various LULCC in Nguruman sub-catchment

	Area (Km^2)			Chi-square Goodness of fit test of			
Land Use Category	**1994**	**2004**	**2014**	**1994-2014**	X^2	**df**	**p**
Cropland	24.90	51.92	70.16	**181.71**	**20.57**	**2**	**0.00**
Forestland	86.17	96.11	102.93	**19.45**	1.28	**2**	0.53
Open grassland	619.63	640.44	716.16	**15.58**	5.15	**2**	0.07
Open water	33.75	69.80	64.77	**91.93**	**13.22**	**2**	**0.00**
Bare land	240.60	200.97	154.64	**-35.73**	**17.82**	**2**	**0.00**
Vegetated Wetland	11.82	13.45	13.54	**14.60**	0.22	**2**	0.89
Wooded grassland	1672.55	1616.73	1567.21	**-6.30**	2.52	**2**	**0.28**

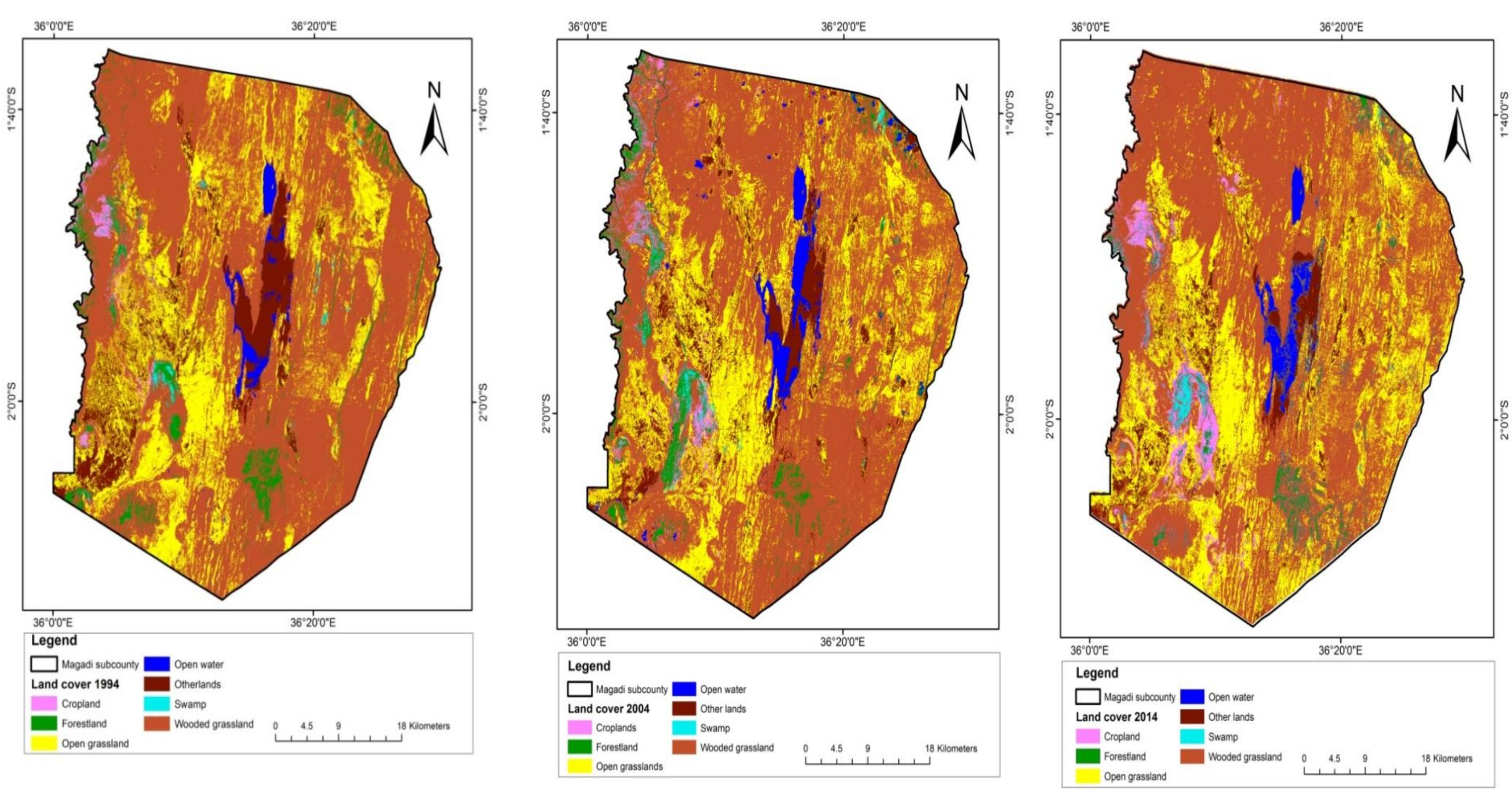


Figure 2. Land Use and Land Cover Changes in Nguruman for Period 1994, 2004 and 2014

ISSN: 2456-8643

Projections of land use land cover change in Nguruman

The 25 year projections (2015-2040) for the land use land cover changes indicated that cropland and open water (Figure 3 and 7) will continue to increase. However, forestland, bareland and swamps will decline in the next 25 years (Figures 5-7). Expansion of cropland is mainly driven by the available opportunity to exploit water for irrigation in Nguruman sub-catchment. This is further driven by demands for horticultural products from the region to nearby markets. The increase in bareland is attributed to increased rates of soil erosion due to loss of vegetation cover resulting from clearing natural vegetation for cropland expansion. Increased soil erosion is directly associated with nutrient loss, which reduces agricultural productivity (Bakker *et al*., 2007). When the productivity is reduced most of the land is abandoned for other fertile grounds. In some cases, advanced stages of soil erosion, such as rill and gully erosions, can devastate entire areas, turning them unsuitable for agricultural purposes (Kirkby and Bracken, 2009).

The findings of cropland expansion are also consistent with land use and land cover projection studies conducted in various parts of Kenya e. in the Eastern arc Mountains (Maeda *et al* 2011). Results of modeling study in the Mara River Basin (Mango *et al* 2011) indicate expansion in agriculture. As predicted for the case of Nguruman sub-catchment this is expected to cause greater water scarcity and exacerbating degradation and expansion of bare land on the landscape due to erosion. Notter *et al* 2007 and Mango *et al* 2011 in the Mount Kenya region noted that agricultural expansion will likely take place predominantly in throughout the next 25years, increasing the spatial dependence on distance to rivers and other water bodies. Consequently this will have an impact on already scarce water resources. There are several reasons for the predicted reduction in future water availability. The most evident is the growing number of water abstractions for irrigation, livestock and domestic purposes (Aeschbacher *et al.,* 2005). This underlines the importance of more efficient water management in the Nguruman catchment area and other semi-arid regions of Tropical Africa.

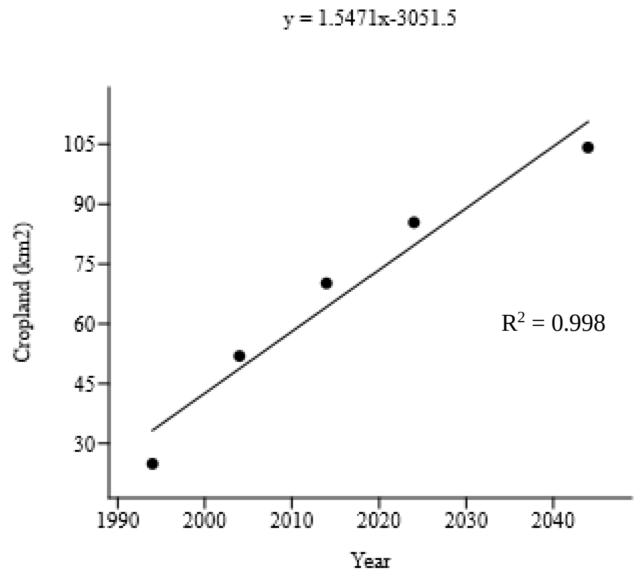
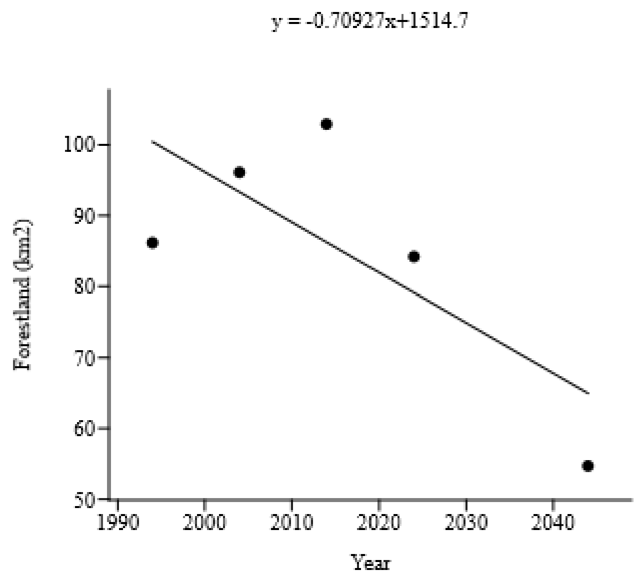


Figure 3. 25 year (2015-2040) cropland projection



Vol. 2, No. 05; 2017

ISSN: 2456-8643

Figure4. 25 year (2015-2040) Forestland projection

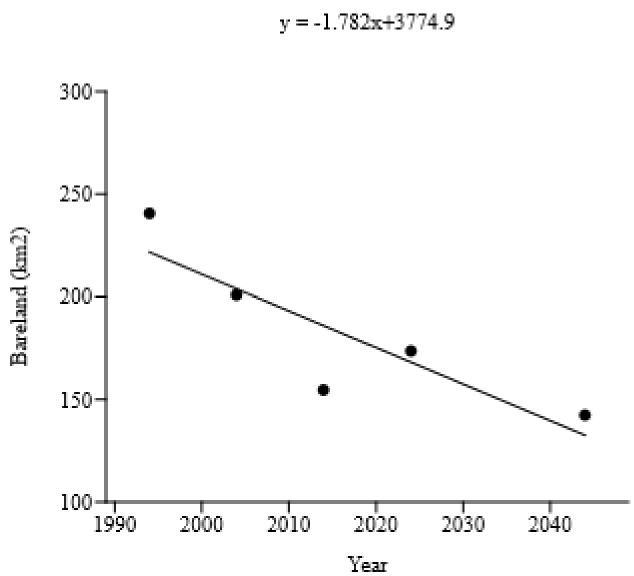


Figure 5. 25 year (2015-2040) Bareland projection

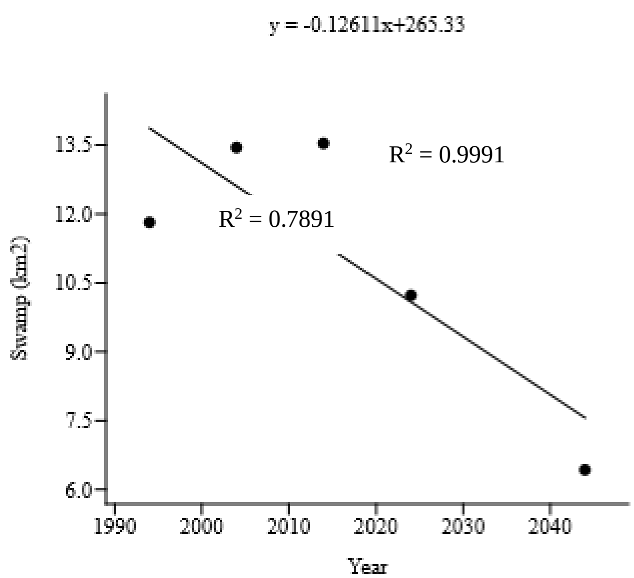


Figure 6. 25 year (2015-2040) Swampland projection

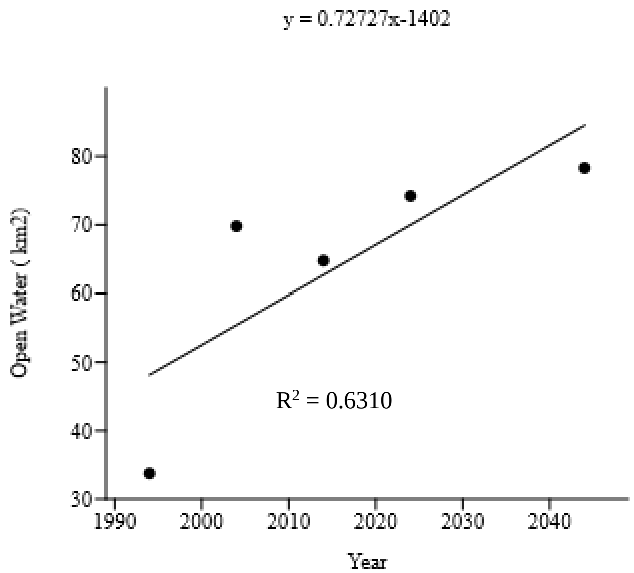


Figure 7. 25 year (2015-2040) projection in Open Water

Conclusions and Recommendations

The findings of this study indicated that significant cropland expansion is the major driver of land use change in the study area. This expansion is driven by the existing opportunity to exploit water from the rivers for irrigation coupled with growing native and immigrant population and ready markets for horticultural products from the region. Cropland expansion in this area is mainly confined along the riparian areas where water is available for irrigation. The land use and land cover predictions indicate cropland will continue to expand in the next two decades. This expansion will greatly impact the integrity of water resources to provide sufficient water for various allocations in the region. Hence it is important to know the consequences of ongoing land use changes open water which is also contributed by runoff will also continue increasing as more natural vegetation that would intercept rainfall is cleared for cropland. As more vegetation is cleared soil erosion and sedimentation are likely to increase leading to increased run off due to reduced percolation. The understanding of the interconnecting relationship between land use and water resource availability involved in this system is an essential step for elaborating public policies that can effectively lead to the sustainable use of water resources. In the absence of urgent measures to curb the negative trends of land use changes projected it is expected that water scarcity and land degradation will continue becoming a challenge. Sound ecological measures should be put in place to reverse these current trends. The results of this study underline the importance of the implementation of a water management plan including specific actions targeted on the development and implementation of sustainable agriculture policies.

The results indicate that, if current trends persist, agricultural expansion will likely take place predominantly along the riparian land in the next 25years, increasing the spatial dependence on distance to rivers and other water bodies. This study highlights the need to protect the riparian land and the matrix of habitats that include the river systems of the catchment area. The main factors driving the spatial distribution of new croplands were the availability of market for horticultural produce and increasing population. Further studies are necessary to integrate the effects of population pressure on the sustainability and characteristics of local agricultural systems.

Acknowledgement

I am greatly indebted to the fraternity and members of staff of the Department of Land Resource Management and Agricultural Technology (LARMAT) who directly and indirectly supported me in the progress of my research work towards its successful completion. I acknowledge with gratitude, the instrumental help provided by Dr. Judith Mbau for sharing her valuable time, energy and suggestions in the initial stages of developing my research project. To my lead field assistance Dismas Ongoro and entire team of enumerators for their tireless efforts in data collection I am very grateful.

Reference

Aeschbacher J, Liniger H, and Weingartner R. (2005) River Water Shortage in a Highland–Lowland System: A Case Study of the Impacts of Water Abstraction in the Mount Kenya Region. Mountain Research and Development. 25:155–162

Ayuyo, I.O., and Sweta, L. (2014). Land Cover and Land Use Mapping and Change Detection of Mau Complex in Kenya Using Geospatial Technology International Journal of Science and Research 3:3

Baaru, M.W and Gachene, C.K.K (2016) Community empowerment through participatory resource assessment at Kathekakai settlement scheme, Machakos County, Kenya , *International Journal of Sociology and Anthropology* Vol.8(2), pp. 15-22

Bakker, M. M., Govers, G., van Doorn, A., Quetier, F., Chouvardas, D., Rounsevell, M. (2008). The response of soil erosion and sediment export to land-use change in four areas of Europe: The importance of landscape pattern. Geomorphology 98 (3–4):213–226.

Baldyga, T.J., Miller S.N., Driese K.L., and Gichaba C.M. (2008). Assessing land cover change in Kenya's Mau Forest region using remotely sensed data. African Journal of Ecology, 46(1) 46-54

Bruijnzeel LA. 2004. Hydrological functions of tropical forests: not seeing the soil for the trees? Agriculture, Ecosystems and Environment 104 (2004) 185–228

Campbell D.J., Gichohi, H, Mwangi, A and Chege, L. (2003). land use conflicts in South East Kajiado District, Kenya.. Land Use Policy 17(5):337-348

Dessie, G., and Christiansson, C. (2008). Forest Decline and its Causes in the South-Central Rift Valley of Ethiopia: Human Impact over a One Hundred Year Perspective. Ambio.37(4):263-71

Ellis, E., and Robert, P.(eds.)(2007). Land-use and Land-cover Change. Journal of Environmental and Earth Sciences 3(4):307-313

Enfors, E. I., and Gordon, L.J. (2007). Analyzing Resilience in Dryland Agro-Ecosystems: A Case Study of the Makanya Catchment in Tanzania Over the Past 50 Years. Land Degradation & Development 18 6

Environmental Systems Research Institute . 2009. ENVI 4.7 and ENVI EX. ITT Visual Information Solutions. ESRI, Redlands, California. USA

Ermias, A. (2006). Monitoring and evaluating land use and land cover change using participatory GIS tools: A case study of Begasheka Watershed, Tigray, Ethiopia. Electronic Journal on Information Systems, Vol. 25 Issue 3:1-10

Environmental Systems Research Institute (ESRI)(2009. ENVI 4.7 and ENVI EX. ITT Visual Information Solutions. ESRI, Redlands, California. USA

FAO (2010). Global Forest Resources Assessment. Main Report. FAO Forestry Paper, 163

ISSN: 2456-8643

Garede, N.M., and Minale, A.S. (2014). Land Use and Cover Dynamics in Ribb Watershed, North Western Ethiopia. Journal of Natural Sciences Research 4:16

Gathaara, V.N., Gachene ,C.K.K., Ngugi, J.N., Thuranira, E.G., and Maaru, M.W. (2010). Adoption and opportunities for improving soil and water conservation measures in Kathekakai Settlement Scheme, Machakos District. Paper presented during the 12th KARI Biennual Scientific Conference, 8 – 12 Nov 2010.

Gete, Z., and Hurni, H. (2001). Implications of land use and land cover dynamics for mountain resources degradation in the north-western Ethiopian highlands. Mountain Research and Development 21:184–191.

Goldewijk, K.K., and Ramankutty, N. (2004). Land use change during the past 300 years. Land Use Land Cover and Soil Sciences I – Encyclopedia of Life Support System

Haller, R., Emberger, G., and Mayerthaler, A. (2008). A System Dynamics Approach to Model Land-Use andTransport Interactions on the National Level. CORP 2008. Vienna.

Haruna, S., Home, P., and Nyadawa, M., (2014). Land use changes across river Nanyuki catchment, Kenya using Claslite and ENVI. International Journal of Advances in Engineering & Technology, 7(4):1161-1169

Ifeka, A.C., and Akinbobola, A. (2015). Land use and land cover change detection in some selected stations in Anambra State. Journal of Geography and Regional Planning 8(1): 1-11.

Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: The Physical Science Basis. Geneva: IPCC Secretariat.

Ioanoannis M, Meliadis M. 2011. Multi-temporal Landsat image classification and change analysis of land cover/use in the Prefecture of Thessaloiniki, Greece. Proceedings of the International Academy of Ecology and Environmental Sciences, 1(1): 15-25

IPCC. 2007. Climate change Synthesis report. Contribution of Working Groups I, II and III to the fourth assessment report of the Intergovernmental Panel on Climate Change. Pachauri RK and Reisinge, A (Eds.). Geneva, Switzerland, 104pp.

Jorgenson, A.K., and Burns, T. (2007). Effects of rural and urban population dynamics and national development on deforestation rates, 1990-2000. Sociological Inquiry 77:460-482.

Kamusoko, C., and Aniya, M. (2007). Land use and cover change and landscape fragmentation analysis in the Bindura District, Zimbabwe. Land Degradation and Development 18:221–233

Kathumo V.M., Gachene C.K.K., Okello J.J, Ngigi M and Miruka M (2015). Is Lower Tana River Forest Complex and EcosystemUnder Threat of Total Destruction? Evidence fromParticipatory GIS in the Sustainable Land Management in Dry Lands of Kenya Improving Land Productivity through Participatory Research and Technology Transfer Khalif Z, Gachene CKK, Gicheru P, Mburu D M and Gakah CG (eds), United Nations Development Programme - Kenya 2015

Kathumo, V.M. (2011). Application of remote sensing and GIS in assessing land use and land cover changes and their impact on hydrological regime in river Gucha catchment, Kenya. PhD Thesis, Department of Land Resource Management and Agricultural Technology, University of Nairobi, Kenya.

Kirkby and Bracken, 2009 Gully processes and gully dynamics. *Earth surface processes and Landforms* 34 (14):1841–1851

Kizza C.L., Tenywa M.M., Majaliwa J.G.M. , Kansiime F. , Magunda M. , Nakileza B. , Barasa . , Gabiri G., Sebuliba E. and Nampijja J. (2017). Land Use/Cover Change Patterns In Highland Ecosystems of Lake Bunyonyi Catchment In Western Uganda. African Crop Science Journal, Vol. 25, Issue Supplement s1, pp. 43 – 58

Kundu, P. M., Chemelil, M.C., Onyando, J.O., Gichaba, M. (2008). The use of GIS and remote sensing to evaluate the impact of land cover and land use change on discharges in the River Njoro Watershed, Kenya. Journal of World Association on Soil Water Conservation 2:109-120.

Lambin, E.F., Geist, H.J., and Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. Annual review of environment and resources, 28(1), 205-241.

Legesse, D., Vallet-Coulomb, C., and Gasse, F. (2003). Hydrological response of a catchment to climate and land use changes in Tropical Africa: case study South Central Ethiopia. Journal of Hydrology 275:67-85

Lu, D., Mausel, P., Brondízio, E., and Moran, E. (2004). Change detection techniques. International Journal of Remote Sensing 25(12): 2365–2401

Maeda, E.E., Clark, B.J.F., Pellikka, P.K.E., Siljander, M. (2010) Modelling agricultural expansion in Kenya's eastern arc mountains biodiversity hotspot. Agricultural Systems, 103 (9), 609-620

Mango, L. M., Melesse, A. M., McClain, M. E., Gann, D., and Setegn, S. G.(2011): Land use and climate change impacts on the hydrology of the upper Mara River Basin, Kenya: results of a modeling study to support better resource management, Hydrol. Earth Syst. Sci., 15, 2245-2258

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, D.C.

Mubea, K., and Menz, G., (2012). Monitoring Land-Use change in Nakuru (Kenya) using Multi-Sensor satellite data. Advances in Remote Sensing 1: 74-84

Mwavu, E.N., and Witkowski, E.T.F. (2008). Land-use and cover changes (1988–2002) around Budongo Forest Reserve, NW Uganda: Implications for forest and woodland sustainability. Land degradation & development, 19(6):606-622.

Ningal, T., Hartemink, A.E., and Bregt, A.K. (2008). Land use change and population growth in the Morobe Province of Papua New Guinea between 1975 and 2000 Journal of Environmental Management 87:117–124

Notter B, MacMillan L, Viviroli D, Weingartner Rand Liniger H. (2007). Impacts of environmental change on water resources in the Mt. Kenya Region. Journal of Hydrology. 343(3-4):266-278

Okello, J.J., Ngigi, M, Kathumo, V.M. (2012). Conserving Lower Tana River Forest Complex in Coastal Kenya: Research Findings and Way Forward.Socioeconomic case study. ENDA Lead Africa

Ostrom, E. (1999). Self-Governance and Forest Resources Occasional Paper No. 20

Otieno, VO and Anyah, RO. 2012: Observed and simulated influence of land use changes on the Greater Horn of Africa climate. Case study over Kenya. *Climate Research.*, *52*,77-95

Parés-Ramos, I.K., Gould, W.A., and Aide, T.M. (2008). Agricultural abandonment, suburban growth, and forest expansion in Puerto Rico between 1991 and 2000: Ecology and Society 13 (2):11.

ISSN: 2456-8643

Pellikka, P.K.E., Lötjönen, M., Siljander, M., and Lens, L. (2009). Airborne remote sensing of spatio temporal change (1955-2004) in indigenous and exotic forest cover in the Taita Hills, Kenya. International Journal of Applied Earth Observations and Geoinformation, 11 (4):221-232.

Reij, C., Tappan, G., Belemvire, A. (2005). Changing land management practices and vegetation on the Central Plateau of Burkina Faso (1968–2002). Journal of Arid Environments 63: 642–659

Rogan, J., and Chen, D.M. (2004). Remote sensing technology for mapping and monitoring land-cover and land-use change. Progress in Planning 61 (4): 301-325.

Nelson, KC; Palmer, MA; Pizzuto, JE; (2009) Forecasting the combined effects of urbanization and climate change on stream ecosystems: from impacts to management options. J Appl Ecol 46(1):154−163.

Sambalino F, Hulshof M, Borgia C ,Tolk L, Kleinendorst T 2012, South Rift Landscape, Kenya: a baseline study part for the Horn of Africa Climate Change Programme, The Netherlands and Kenya

Saran, S.; Sterk, G.; Kumar, S. (2009). Optimal land use and land cover classification using remote sensing imagery for hydrological modeling in a Himalayan watershed. Journal of. Applied Remote Sensing. 3:1 - 16.,

Shalaby, A., and Tateishi, R. (2007). Remote sensing and GIS for mapping and monitoring land cover and land use changes in the North-Western coastal zone of Egypt. Applied Geography 27(1): 28-41

Singh P and Khanduri K. 2011: Land use and Land cover change detection through Remote Sensing &GIS Technology: Case study of Pathankot and Dhar Kalan Tehsils, *International Journal of Geomatics and Geosciences*: 1:4

Steffen, W. (2004). Global Change and the Earth System.. The Anthropocene Era: How Humans are Changing the Earth System pp 81-141 Springer-Verlag, Berlin

Syombua, J.M. (2013). Land use and land cover changes and their implications for human-wildlife conflicts in the semi-arid rangelands of southern Kenya. Journal of Geography and Regional planning 6(5):193-199

Templer, P.H., Groffman, P.M., Flecker, A.S., Power, A.G. (2005). Land use change and soil nutrient transformations in the Los Haitises region of the Dominican Republic. Soil Biology & Biochemistry 37:215–225

Tilman, D., Lehman, C. (2001). Human-caused environmental change: impacts on plant diversity and evolution. Proceedings of the National Academy of Science U.S.A. 98:5433–5440.)

Treitz., P.; Rogan, J. (2004) .Remote sensing for mapping and monitoring land-cover and land-use change —An introduction. Prog. Plann., 61, 269–279.

Tsegaye D, Moe SR, Vedeld P, Aynekulu E (2010). Land-use/cover dynamics in northern afar rangelands, Ethiopia. Agriculture, Ecosystems and Environment 139: 174-180.

Turner M. 2003. Critical reflections on the use of remote sensing and GIS technologies in human ecological research. *Human Ecology*, 31(2): 177–182.

Wanjiku, M. (2015). Assessment Of Changes In Land Use And Land Cover And Soil Erosion Risk Factors In Kathe-Kakai Catchment, Machakos County, Kenya. Bsc Thesis, Department of Land Resource Management and Agricultural Technology, University of Nairobi, Kenya.

Zeleke, G., Hurni, H. (2001). Implications of land use and land cover dynamics for mountain resource degradation in the northwestern Ethiopian highlands. Mountain Research and Development 21(2):184-191

Zuazo V.H.D. and Pleguezuelo C.R.R. (2008). Soil-erosion and runoff prevention by plant covers: a review. Agronomy for Sustainable Development, *28* (1):65-86