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Land use, land cover change in urban pastoral interface. A case of Kajiado County, Kenya

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Suitable location and influx of immigrants have made pastoral peri-urban Kajiado County a centre of two conflicting interests; urban sprawl and agricultural intensification. To understand the resulting trends over the period 1984-2010 satellite image based analysis of land use cover changes and interviews with landowners were conducted. Interviews focused on the changes and trends in land use, their causes and future forecasts. Percentage changes in land use and land cover types for the years 1984 to 2004, 2004 to 2010 and 1984 to 2010 were determined. Between 1984 and 2010, significant ($p < 0.05$) changes occurred in built-up, crop land, rangelands, bare ground, rocky areas and woodlots and riverine vegetation. Only water bodies showed no significant changes. Land use and cover changes resulted from activities due to human population growth and agricultural expansion which in turn resulted in increase in riverine vegetation and woodlots. The interviews revealed that selling of land contributed to land use change depending on the intended use of the buyers who were mainly influenced by the physical location with respect to distance to Nairobi, urban centres, electricity supply and road networks. As per the findings of the study, the present scenario demands a revision in the zoning policy using the land use land cover maps produced, involvement of all stake holders and revision of implementation strategies given that the 2008 land use master plan for the area was not actualized.

Key words: Pastoral peri-urban, immigrants, land use change, intended land use, Kajiado County.

INTRODUCTION

Land use is defined by the purposes for which humans exploit the land cover. Proximate causes of land use change are the activities and actions that directly affect land use, for example road building whereas the underlying causes are the fundamental forces that underpin the proximate cause like demographic, economic, policy, technological, institutional and cultural factors (Lesschen et al., 2005). There is high variability in

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time and space in biophysical environments, socio-economic activities, and cultural contexts that are associated with land-use change. Identifying the causes of land-use change requires an understanding of how people make land-use decisions and how various factors interact in specific contexts to influence decision making on land use. Decision making is influenced by factors at the local, regional, or global scale (Lambin et al., 2003).

Kenya has experienced rapid changes in land policies that have transformed former pastoral communal lands into group, individual ranches and private holdings. These changes in land tenure systems have led to an emergence of several land-use systems (Kristjanson et al., 2002; Mwangi, 2006). According to Olson, (2006) in East Africa the spatial pattern of land use change for the past 50 years has been characterized by increasingly intensively managed landscape. The driving forces in land use change include demographic changes (local population growth and migration), economic changes (higher relative returns to labour and land in crops than livestock), policies (e.g. land privatization, support for export crops), and changing quality of and access to services and infrastructure (Olson, 2006; Bee et al., 2002; Mwangi, 2006). The world is currently experiencing massive demographic changes through differing rates of natural increase and net migration. Cohen (2004) reveals that the absolute scale of urban change that will be faced in the African continent countries by 2025 will occur in smaller secondary cities and towns similar to Peri-urban Kajiado North District.

Peri-urban areas are the transitional zones between rural and urban landscapes that experience constant population change and disturbance of traditional social, environmental, and economic characteristics (Stockwell et al., 2013) reckons as a result sustainable community development initiatives are complicated in these fragmented and often contested landscapes. The population increase naturally creates adjustment and readjustment of human and land use activities in space within urban systems thus causing lateral and structural changes (Oluseyi, 2006). Population data are considered the principle source of information on growth of cities (Cohen, 2006). Lateral changes occur when the city expands in geographic boundaries leading to sprawl and peripheral developments. The low density areas gradually become subjected to intensive use and thus become high density or medium density use (Oluseyi, 2006).

Initiatives by stakeholders and Kenyan Government from year 2000 try to limit the land cover land use change and offer guided development given that the area is dispersal and corridor for wildlife from Nairobi National park. A Wildlife Conservation Lease Program (WCLP) was started in year 2000 (Republic of Kenya, 2008: Reid et al., 2008) by the community in partnership with; the Wildlife Foundation, Friends of Nairobi National Park, African Wildlife Foundation, The Nature Conservancy and the World bank, the program requires participants to allow free movement of wildlife on their land, protect natural vegetation, and avoid fencing or sub-dividing their land. Under WCLP landowners are paid a lease fee of four dollars per year whereby entry and exit to the program is voluntary (Republic of Kenya, 2008; Reid et al., 2008). Similar initiatives have been done in USA successfully (Knight, 2002; Bernstein and Mitchell, 2005; Ferguson, 2009) to protect natural or cultural resources. The Kitengela-Isinya-Kipeto land use master plan (LUMP) covering the Kajiado North District drafted in 2008 zones and gives a guideline on minimum land holding sizes with respect to uses in livelihood production activities in designated areas (Republic of Kenya, 2008). This study sought to analyze the trends in land cover and land use changes, human population growth land price trends and assess the community perception on environmental easement and zoning with respect to land use master plan for the area.

METHODS AND MATERIALS

Study area description

The study was carried in the pastoral peri-urban area of Kajiado North District that lies between South of Nairobi City and Nairobi National Park in Kenya. The study area covers 1631.18KM^2 and is located between 36^o 37'E to 37^{o}8'E, and 1^{o}23'S to 1^{o}49'S (Figure 1). The District receives a bimodal regime of rainfall, short rains in October – December and long rains in March-May. The annual average rainfall is between 300 and 1300 mm, but it is both unevenly distributed and unreliable. Temperature varies between 13 and 25^{0}C throughout the year. The district is largely semi–arid and lies in agro-climatic zones III to VI with zones IV and V being the most predominant (Jaetzold et al., 2011). This means that the area is mainly suited for ranching activities and early maturing crop varieties. The soils are predominantly Vertlsols with poor drainage and cracking clay.

The area was originally occupied by the pastoral Maasai but currently the population is multi-ethnic due to immigrants who came from other parts of Kenya as land tenure policy changed (Rutten 1992; Olson, 2006). Crop production and intensive livestock production is done mainly by immigrants from other tribes (Jaetzold et al., 2011) while natives are in transition to agro-pastoralism. The district has many land use systems in place; some that have remained in their original uses while others have various uses as a result of single to multiple changes over time through activities like sub-division, sales, quarrying and diversification (Kristjanson et al., 2002). The area serves as a dispersal area for wildlife with calving sites for the wildebeest and movement corridor from Nairobi National Park that necessitated the easement programme (Reid et al., 2008).

Land use and land cover changes analysis

Satellite images were analyzed in conjunction with ground truthing observations as proposed by Thomas and Ayuk (2010) and Kumar et al. (2014). A hand held Global Positioning System (GPS) was used in the ground truthing exercise to ensure that features on ground are in their correct planimetric position on the images. Seven land use classes; range land, bare ground, water body, rocky areas, built-up, crop land, riverine vegetation and woodlots were delineated as the major land use cover types. Weeks (2003) recommends the use of at least two time-period data sets to detect

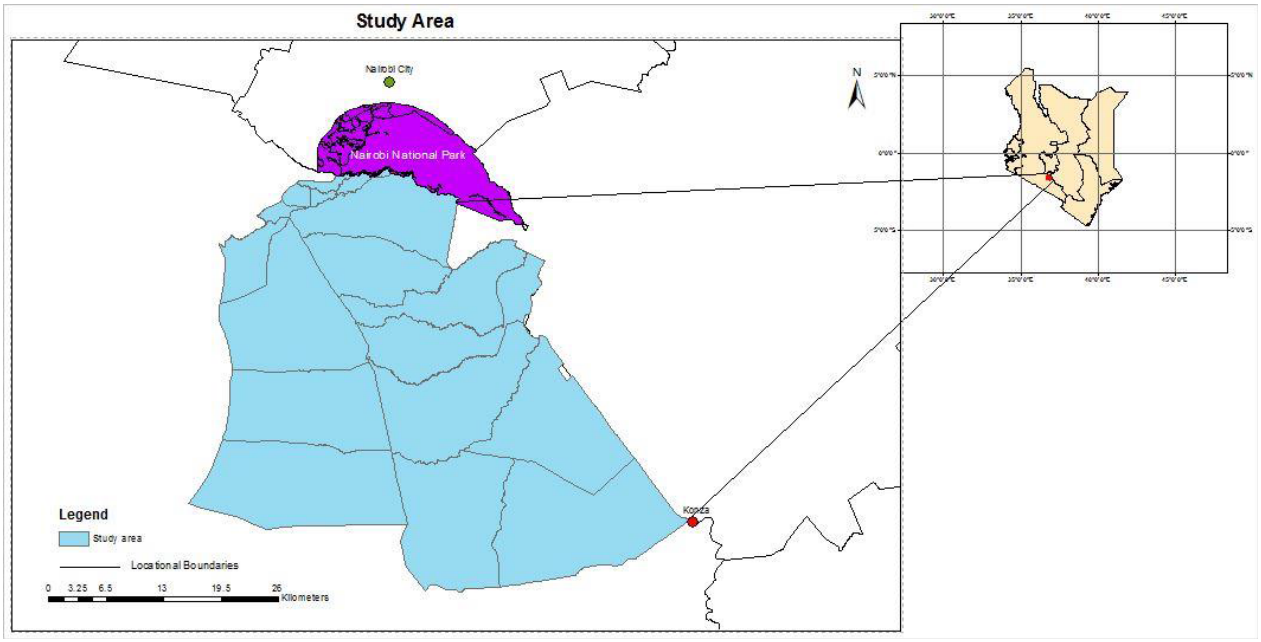

Figure 1. Map of Kenya showing the study area.

changes in land use and land cover through processes such as urban sprawl, because it is change in places over time that we must measure and analyses essentially measure the impact of human settlement by quantifying the change. In this study, three time period Landsat images, that is, one Thematic Mapper (5TM), and two Enhanced Thematic Mapper plus (7 ETM+), for the study area for the years 1984, 2004 and 2010 respectively were analyzed. The images were downloaded from USGS Global Visualization Viewer (GLOVIS, URL: http://glovis.usgs.gov). The selection of the image was based on the acquisition date (season), availability, spatial resolution, percent cloud cover as well as the user need and scale of the study area. A total of 21 spectral bands were downloaded and stacked according to construct 7 band Land Sat TM images for each date (27/8/1984, 23/9/2004 and 19/8/2010). All images coincided with dry season before the onset of short rains in October to avoid uncertainties.

Image classification

Land use and land cover maps were developed from the satellite images through defining spectral classes by clustering image data and assigning pixels into classes. Multi-temporal Landsat data processing was done using ENVI 4.7 software (ESRI, 2009). Regions of Interest (ROI) were defined to extract statistics for classification. Supervised classification was used with false colour composite bands (4, 3, and 2) to cluster pixels in a dataset into classes corresponding to the selected ROI. Supervised classification techniques used to classify the images included minimum distance and maximum likelihood (ESRI, 2009). Seven land use and land cover types were classified according to Andersen (1998)'s guidelines as; range land, bare ground, water body, rocky areas, built-up, crop land, riverine vegetation and woodlots.

Change detection

Change detection was done for the classified land use and land cover types. ENVI EX Software (ESRI, 2009) was used for thematic change detection by comparing two images of different time periods (1984 and 2004 images, 2004 and 2010 images) and overall change between 1984 and 2010.

Community interviews

The household survey was carried out with a sample of randomly selected respondents with a pre-tested questionnaire. Households to be interviewed were randomly selected from the sampling frame developed through generating of random numbers (Aaker et al., 2003) assigned after homestead mapping with help of the local sub-chiefs and village elders of administrative areas from the households in each sub-location. The household was the sampling unit whereby both natives and immigrants were interviewed in the settlement clusters of urban, rural/urban and rural sub-locations. For each household, husband and wife were interviewed. In cases where a man had multiple wives, the resident woman in the household was selected for interview. Interviews were also carried out with women who were heads of households. A questionnaire containing both open-ended and closed-ended questions was administered to four hundred and nineteen households.The interviews were done by trained enumerators under the supervision of the principal researcher. The parameters covered included causes of land use/land cover change, current and future trends, and community perception on environmental easement and zoning with respect to land use master plan.

Observations

Unstructured participant observation took place during household survey in the field (Taylor-Powell and Steele, 1996; Russell, 2006). Unstructured participant observation was used in particular because it allowed the researcher as an insider to be specific as to when and where to observe, what specific aspects of the setting or behaviour to observe, and how to make and record observations.

Photographs were taken of key indicators of trends in land cover

land use change.

Human population and land price trends

Human demographic data spanning from 1979 to 2009 population census were collated from the Kenya National Bureau of Statistics (KNBS) of the Republic of Kenya. This was compared to the land use and land cover change data to establish if there was any relationship between land use change and human population trends. The household survey gave the price trends for the land with respect to physical location for the period 1980-2010.

Data analysis

The area of land under different land uses and cover was used to calculate percentage changes in land use and land cover using Excel software. This was also applied to prices of land under different physical locations. Overall land use and cover changes were calculated from the 1984 and 2010 land sat images analysis statistics and price trends were calculated from 1980-2010 household survey analysis statistics. Chi-square goodness of fit was used to determine if there were significant changes in land use and land cover (Wayne, 2010). Linear regression was used to show the relationship between land use change and human population growth with time (Wayne, 2010). Data from the household interviews were summarized into frequencies of responses.

RESULTS

Change in land use and cover

The Land sat images for years 1984,2004 and 2010 were classified and quantified to seven broad categories of land use and land cover types (FAO, 2011); range land, bare ground, water body, rocky areas, built-up, crop land, riverine vegetation and woodlots (Figure 2). The spatial extents of each category and their percentage changes are tabulated in Table 1. Rangeland, rocky and bare ground decreased while crop land built-up, woodlots and Riverine vegetation increased during the study period. By 1984, built up was confined to a small radius within urban centres but by 2010 it had spread along the road network near urban centres. The most drastic expansion occurred between 2004 and 2010 with more than 500% increase; meanwhile for the entire study period built up increased by 1531.72%. Crop land increased throughout the period of 1984-2010 by 1024%.

Rangeland which consists of forage shrubs and grass decreased throughout the period of the study by 31.45%. This change was significant ($p<0.001$) given that the area is pastoral but overall it covers the largest area in the study location by 44% equivalent to 71828Ha (Table 1). The change in woodlots and Riverine vegetation was impressive given their contribution to the environment. The overall change in Riverine vegetation and woodlots between the three time periods was 2960% increase. This was probably due to immigrants planting trees around their compounds and establishing woodlots of eucalyptus in addition to the spread of the riverine vegetation along the seasonal rivers.

Between 1984 and 2004, major declining changes were observed mainly in rocky, rangeland and bare ground. Cropland increased from 3187Ha in 1984 to 35843Ha in 2010, which is equivalent to 1025% increase due to activities from the immigrants and natives who had adopted crop production over the years. Compared to all the other land use and land cover types, rangeland showed the least overall changes of 31.42%. Bare land showed the second least overall changes with a decrease of 34.31%. Bare ground and range land combined covered a total area of 95503Ha equivalent to 58% cover of the area by 2010. This means that pastoralism was still the main activity in the area given that the bare lands turn to grass lands during the rainy season. The water bodies had no significant change ($p>0.05$).The image classification result from the landsat images in land cover land use changes between 1984 and 2010 and chi square goodness of fit test to show whether the changes were significant (Table 2).

Human population trends

Human population increase in the district was steady and strongly related to time (Figure 3). Although human population increased throughout the three census periods, a sharp increase occurred between 1999 and 2009 compared to all other time periods. Overall, the study area had a population growth rate of 5.1% between 1989 and 1999 while the rate increased to 16.5% per annum for the period 1999 to 2009 with a population density of 111.6 individuals per Km^2 in 2009. From 1989 to 2009 the area experienced an average annual growth rate of 15.07 % (Republic of Kenya, 1989; Republic of Kenya, 1999; Republic of Kenya, 2009). The population trends between 1989 and 2009 are illustrated in Figure 3.

Land price trends

The urban areas exeprienced the highest price increase per acre during the period 1980-1990 of 190% per year while the rural areas experienced highest price increase during the period 1990-2000 of 90% per year. The respondents gave the average price of land per acre with respect to physical location as tabulated in Table 3.

Causes of land use change

The household survey revealed that sale of land was the major cause of land use change; 94% of the sold land under went change since the new buyers converted it to their intended use. While 6% was due to coping strategies adopted to ensure food security and meet other livelihood needs. Basic amenities like electricity, water, access roads and distance to urban centres influenced buyers' choice of physical location by 75%

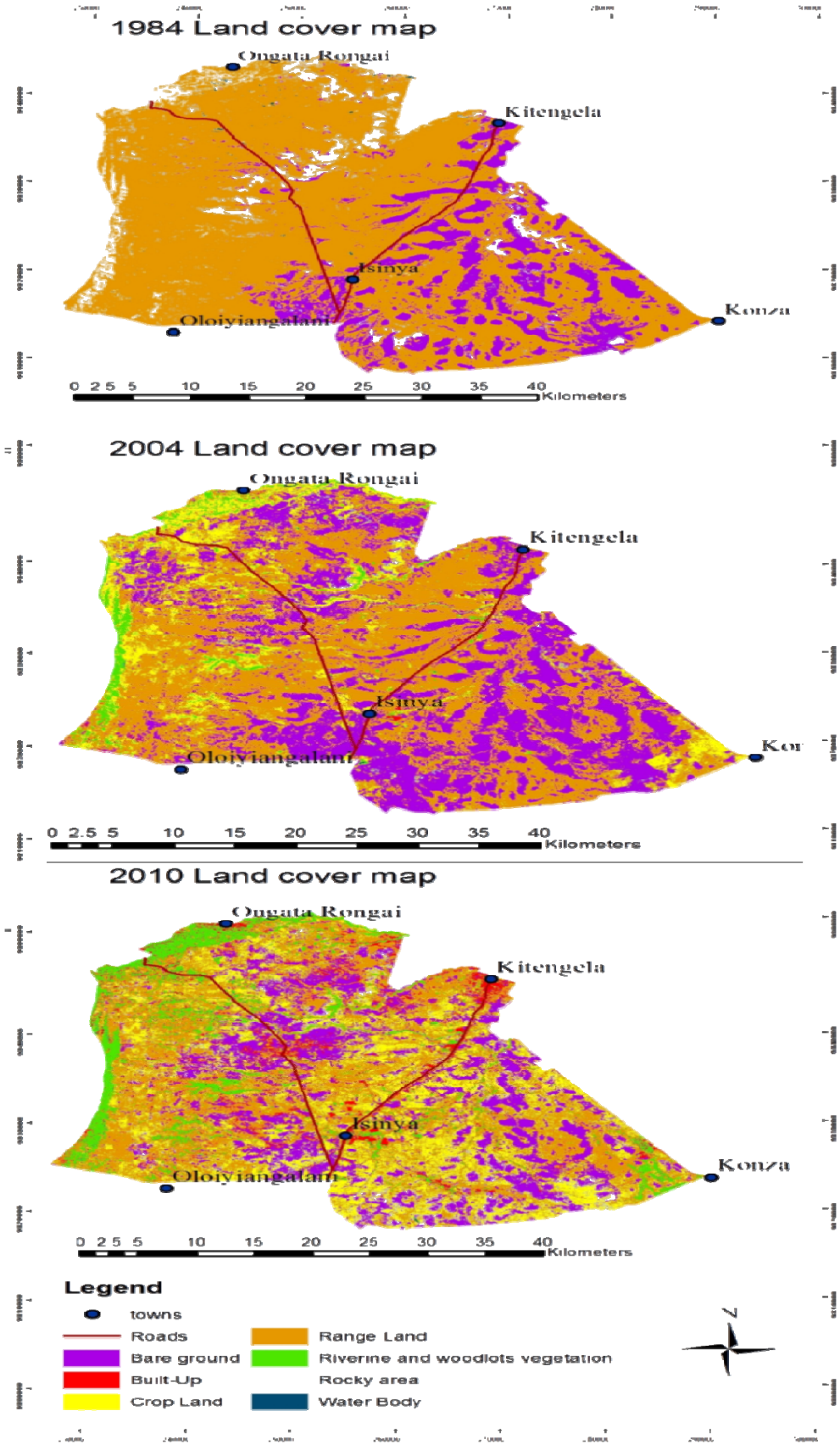

Figure 2. Land use/cover classification results.

Table 1. Extent and proportions of different land use/cover types for the period 1984-2010.

Class Name	1984 Area (Ha)	1984 % area cover	1984-2004 % change	2004 Area (Ha)	2004 % area cover	2004-2010 % change	2010 Area (Ha)	2010 % area cover	1984-2010 % change
Rocky area	18203.96	11.16	-35.34	11771.28	7.21	-25.24	8799.6	5.39	-51.66
Bare ground	36040.1	22.09	-5.24	34150.8	20.92	-30.68	23674.7	14.51	-34.31
Range Land	104740	64.18	-9.74	94540.1	57.93	-24.02	71828.1	44.02	-31.42
Riverine and woodlots	507.25	0.31	820.29	4668.21	2.86	232.57	15525.1	9.51	2960.62
Crop land	3187.28	1.95	427.07	16799.2	10.29	113.36	35842.6	21.96	1024.55
Built-Up	457.80	0.28	168.09	1227.32	0.75	508.65	7470.04	4.58	1531.72
Water Body	50.34	0.03	-40.79	29.80	0.018	56.15	46.54	0.029	-7.55

Table 2. Chi-Square goodness of fit test for the various land use /land cover changes in Kajiado North district between 1984 and 2010.

Class name	1984 Area Km^2	2004 Area Km^2	2010 Area Km^2	1984-2010% change	X2	df	P
Rocky area	182.04	117.71	88	-51.66	36.375	2	<0.001
Bare ground	360.4	341.51	236.75	-34.31	28.47	2	<0.001
Range Land	1047.4	945.4	718.28	-31.42	62.725	2	<0.001
Riverine and woodlots	5.07	46.68	155.25	2960.62	172.54	2	<0.001
Crop land	31.87	167.99	358.43	1024.55	289.64	2	<0.001
Built-Up	4.58	12.27	74.7	1531.72	94.71	2	<0.001
Water Body	0.5	0.3	0.47	-7.55	0	2	1

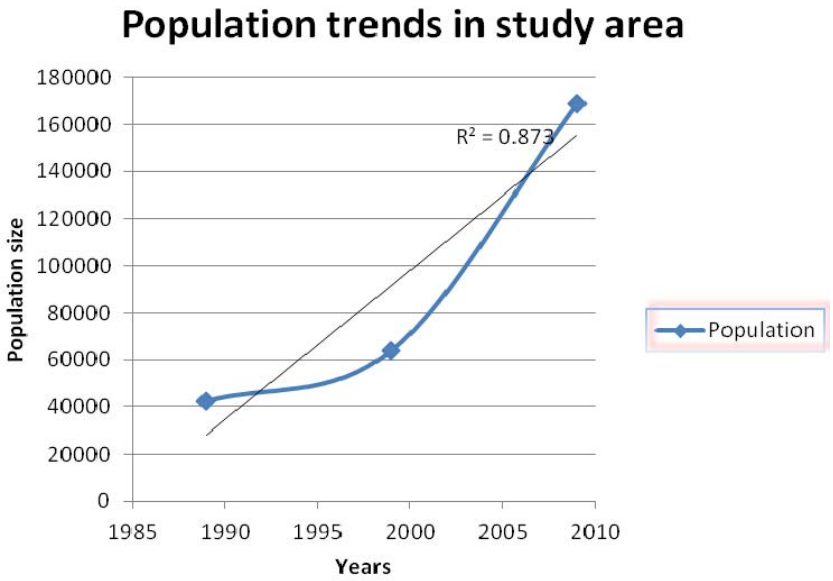

Figure 3. Human population trends between 1989 and 2009. Source Kenya National Bureau of Statistics 1989, 1999, 2009.

while the rest bought for speculative purposes like price appreciation and the upcoming Konza techno-city. The sellers were influenced by peer pressure (60%) to enable them afford good lifestyles (cars and houses), temptation from appreciating prices (20%), low age of household head (5%) while 15% were influenced by several factors

Table 3. Trends in land prices and %change for years 1980-2010.

Physical location	Land prices in ksh/acre ('000')and percent annual change						
	1980 Average Price/acre	1990 Average Price/acre	1980-90 annual % price increase	2000 Average Price/acre	1990-2000 annual % price increase	2010 Average Price/acre	2000-2010 annual % price increase
Urban	10	200	190	1,000	40	15,000	140
Rural	3	10	23	100	90	600	50

Table 4. Complaints associated with easement program.

Complaint	% of respondents affected
Discouraging low compensation rate	85
Stiff competition with the livestock for water and pasture especially during the dry periods given that there is a decline in land holding capacity	60
Wildlife facilitates the transmission of certain livestock diseases e.g. East Cost fever (ECF), increasing veterinary care costs and high mortality rates	50
Maintaining fences around homesteads and other structures, indirectly through labour	68
Livestock predation and destruction of crops by wildlife	90

which included but not limited to education level of household head and brokers.

Community perception on environmental easement and zoning with respect to land use master plan

The environmental easement level of awareness was low at the time of program inception, 27% with mistrust of the natives' thinking that it was a ploy to acquire their land forcefully and they were not certain that they will receive compensation. On the future of the program 72% of the respondents recommended that the easement programme to be done away with and make Nairobi national park a zoo. Meanwhile, 13% of the respondents recommended that the wildlife corridor land should be bought from farmers at market rate and fenced off to be used by wildlife alone and finally 15% felt that the residents should be encouraged to participate in the easement programme by increasing the compensation rate. The natives did not mind wildlife mixing with livestock but they had some complaints as Tabulated in table 4.

In the household survey results for LUMP, 68% recommended revision with more participation of all stakeholders on the ground since majority of buyers were absent when it was done last, 22% recommended enforcement due to land commoditization and degradation and 10% said the government should forget about it since the land was already too fragmented and trend was bound to continue with succession and population increase. Finally, 34% of the respondents considered the area to have undergone degradation due to human activities and invasive weeds during the study period.

Observations

Several cooperatives societies have bought large pieces of land for subdivision to members and private educational institutions for expansion purposes. Observations revealed that most immigrants have established woodlots which are about 10-15 years old as they plant trees and live fences around their compounds. There is increase riverine vegetation comprising acacia species, *A.kirkii* and *A.elatior* (*Olerai* –local maasai name) established along dry river beds of seasonal rivers as they are well adapted. Homesteads have been abandoned due to invasive live fencing of *Opuntia subalata;* meanwhile, large areas of rangelands are covered by the invasive ipomoea weed. Gypsum mines and stone quarries have left large un-rehabilitated areas with plenty of resultant wastes. Some indicators of land use change as captured in the field photographs are shown in Figure 4.

DISCUSSION AND RECOMMENDATIONS

Satellite image analyses showed that land use and land cover changes have occurred in the study area between 1984 and 2010. Pastoral and wildlife dispersal areas were converted to settlement areas leading to general increase in crop land, woodlots and Riverine vegetation. The household survey revealed that land use and land cover changes in this district have been occasioned by

Figure 4. Indicators of land use change as captured in the field photographs.

the increased demand for land resources for individual and institutional property developments together with agricultural activities, infrastructural improvement and population increase. Increased crop production was done to address food security and by immigrants from high potential areas (Jaetzold et al., 2011), who naturally do crop cultivation. Same scenario of increase in crop production has been witnessed in similar pastoral areas (Lynn, 2010) where pastoralists adopt crop production due to changing cultural and social norm to be food secure. McCabe et al. (2010) reckon that the Maasai in North Tanzania had to adopt crop production to remain pastoralists. In semi arid Ethiopia (Desta and Coppock, 2004) and in Kenya (Bebe et al., 2012), decline in household per capita cattle holdings and population pressure led to diversification to crop production to achieve food security and improve their livelihood.

There was general decrease of both range land and bare ground between 1984 and 2010, leading to decline of part of the district which is also a pastoral and wildlife corridor/dispersal area. The degradation in the area also contributed to a decrease in range lands and was mainly

attributed to increased human activities like cultivation, waste disposal, and introduction of invasive species *like Opuntia subalata* (introduced for fencing to secure homesteads) and *Ipomoea kutensis* (covering large areas of the range lands), un-rehabilitated stone and gypsum quarrying mines. The future forecast of pastoral activities is bound to decrease since most range lands are either degraded or in accessible as they are fenced off by the new owners as observed during data collection (Reid et al., 2008: Nkedienye et al., 2009).

The trends in water bodies can be attributed to decline in the water pans and dams which were done in the 1980s by the Ministry of Livestock Rutten (1992) and had silted in 2000 (Republic of Kenya (2008); but again individuals and the government initiated construction to address declining water availability through the Arid Lands Resource Management Project Republic of Kenya (2010). The time period coinciding with the highest population increase (1999 to 2009) also coincides with the highest increase in Riverine vegetation and woodlots, corresponding increase in human dominated activities of agriculture as the rocky decreased due to excavation of building material. The increase in woodlots and Riverine vegetation is actually beneficial to the ecosystem given that forests ecosystems play a key role of maintaining biological diversity and provide environmental services to humans and nature (UNEP, 2002).

Kajiado North area is experiencing increased fragmentation (Rutten M., 2008; Nkedienye et al., 2009); as a result of an influx of immigrants and institutions of higher learning, the most probable trend in the next five years will be an increase in built –up area and crop land. There appears to be a relationship between land use change and human population growth dynamics in Kajiado North district. Brockerhoff (2000) defines a sprawled urban area as one in which land is developed by roads, buildings, and other infrastructure at a faster pace than population growth which is actually the case given that built up increased by more than 1531% as population increased by 15.07% during the study period. Increased fragmentation of pastoral land in the peri-urban area of Kajiado North district is mainly caused by urban sprawl as can be confirmed by the population trends and increase in built-up areas. This situation is made worse as no physical plan (G.O.K., 2008: Kioko and Okello, 2010) is used to direct developments.

Uncontrolled sprawl resulting from informal settlements in the absence of government guidelines and enforcement is a reality in many Eastern African cities UN-Habitat, (2010) and in developing regions, urban expansion has taken the form of 'peripherization' that is characterized by large peri-urban areas with informal and/or illegal patterns of land use (UN-Habitat, 2013;UN, 2013). According to UNEP (2002), most activity addressing urban sprawl takes place at the planning level of government as found out when comparing Canada and USA; where in the former the government planned from the start by instituting long range transportation systems. However in much of Sub-Saharan Africa (UN-Habitat, 2010), decision-making has been only consultative rather than genuinely participatory, with the attendant lack of effective impact, a scenario we can identify with in study area's LUMP of 2008; hence revision should be in accordance with the views of all current land owners to guide and control development.

The easement programme may not achieve much in the study area due to increase in population and fragmentation. There is need to explore other options while taking the residents' recommendation of government to buy the wildlife corridor like Transfer of Development Rights (TDR), (Pruetz and Standridge, 2009; Cohn and Lerner, 2003; Walls and McConnell, 2007), which is a mechanism for preserving farmland, open space, and natural resources practised in United States of America for more than 40 years. In the United States of America TDR and easements have success stories (Walls and McConnell, 2007; Jacobs, 2014; Ferguson, 2009) in several States where forests, wetland and landscapes have been conserved as TDR markets work as a land preservation tool when landowners are willing and able to sell development rights, and developers are interested in buying those rights. The low compensation rate can be addressed by benchmarking with Tanzania where a collaborative easement arrangement with the stakeholders achieved conservation of designated areas successfully as the local community earned more than compensation per hectare since creative mechanisms for channelling benefits to communities were developed as the natural resources were managed in a bottom-top approach (Sachedina and Nelson, 2012). In African communities, Elliott and Sumba (2010) identify six characteristics of a conservation enterprise that is more likely to work well through linking livelihood benefits with conservation gains: clear conservation logic, commercial success, right private sector partner able to perform collaboratively, sound community partner with appropriate governance in place, contractual community ownership and enforcement of benefit streams, transparent intra-community benefit-sharing arrangements and most of these were missing in the current easement program.

In conclusion, the adoption of major land use reforms through laws, plans, regulations, capital improvement plans, data and research reports can only occur when there is the right combination of leadership and public opinion in a comprehensive way as recommended by ILUASC (2010) and Belton (2012) in the USA. In essence all stakeholders must be involved in decision making and implementation for success of land use land cover initiatives. When considering the easement programme, the residents should get benefits from wildlife earnings and they should not feel exploited by low compensation rates.

Conflict of Interests

The authors have not declared any conflict of interests.

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