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Land use and land cover changes and their implications for human-wildlife conflicts in the semi-arid rangelands of southern Kenya

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Land use and land cover changes are important processes that influence the ecological integrity of wildlife dispersal areas and the dynamics of human-wildlife conflicts in rangelands around protected areas. This study investigated trends in both land use and land cover changes in Taveta District. Remote Sensing imageries for Taveta District were analysed for the years 1987, 2001, and 2011. Percentage changes in land use and land cover types for the years 1987 to 2001, 2001 to 2011 and 1987 to 2011 were determined. Between 1987 and 2011, significant (p < 0.05) changes occurred in woodlands, sisal plantations, rainfed and irrigated agricultural areas. Shrublands, forests and water bodies showed no significant changes. Wildlife habitats are expected to further decrease significantly due to agricultural expansion. Land use and cover changes resulted from agricultural expansion and human population growth. The land use and cover maps produced can be used as input to decision making that balances restrictions on human land use while maintaining the ecological function of the landscape, through designation of Zones of Interaction as a first step to identifying opportunities that satisfy conservation and livelihood needs. Proper land use planning and community awareness of the implications of these land use and land cover changes are necessary.

Key words: Land use change, land cover change, rangelands, Taveta district, human-wildlife conflicts.

INTRODUCTION

In developing countries, the livelihoods of most of the human population depend almost entirely on natural resources. Thus there exists increasing competition between the utilization and sustainable management of land resources and a need to monitor land use and land cover changes over time. "Land use" refers to what people do on the land surface, that is, the manner in which human beings employ the land and its resources (e.g., agriculture, settlement etc). "Land cover" defines the ecological state and physical appearance of the land surface (e.g., water, crops, forest, human structures, shrubs etc) (Turner and Mayer, 1994; Brandon, 2001; Geist and Lambin, 2002). Worldwide, land cover change is caused by changes in the way people use and manage

land (Millennium Ecosystem Assessment (MEA), 2005a). This occurs mainly from direct effects of population growth such as agricultural expansion, grazing and land for settlement as well as indirect effects of pollution (UN/ECE, 2002; MEA, 2005b).

Rangelands outside protected areas are important wildlife dispersal areas that have declined over time. This has been attributed to land fragmentation, occasioned by subdivision of group ranches and leasing of land to newcomers/immigrants practicing agriculture as well as the changing lifestyles of the pastoral communities within the rangelands (Kioko and Okello, 2010). Land use and land cover changes around protected areas could have far reaching implication for wildlife conservation. Such

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areas are important for providing daily and or seasonal forage and water resources, breeding grounds, mating opportunities (Newmark, 1993; Okello and Wishitemi, 2006) or act as migratory corridors by wildlife residing in the parks. Despite their importance, dispersal areas around protected areas are exposed to land use and land cover changes due to livelihood demands by local communities, a situation that challenges the reliability of protected areas for wildlife conservation.

Among the challenges posed by land use and land cover changes around protected areas is the escalation of human-wildlife conflicts (FAO, 2009). The conflicts have been on the increase and are a major challenge to wildlife managers and conservationists in many countries, Kenya included (Hoare and Du-Toit, 1999; FAO, 2009; Kenya Wildlife Service, 2012). Taveta District has been experiencing intensification of human-wildlife conflicts for resources, which are also considered the third factor that has contributed to poverty in the district (Kamande, 2008; Republic of Kenya, 2011). The district lies adjacent to Tsavo West National Park which is one of Kenya's top six human-wildlife conflict hotspots (Kenya Wildlife Service, 2012). Considering that the demand for land for settlement and crop production is likely to increase in the face of Kenya's high population growth rate of 2.9% p.a (Republic of Kenya, 2009) and most of the pastoral communities are changing their lifestyle in favour of farming, land use and land cover changes will continue to challenge wildlife conservation in this district. The information on land-use and land cover changes and their drivers is an important input in the formulation of policies and programmes required for development planning at both local and national levels, as well as for projecting the consequences of these changes on the conservation of natural resources, and their sustainable management (Petit et al., 2001; Dovie et al., 2005; Palmer et al., 2005). This study sought to analyze trends in land use and land cover changes and human population growth, as some of the known causes of conflicts to establish their possible contribution to human-wildlife conflicts experienced in Taveta District. Land use and land cover changes were analysed from multi-temporal images and ground truthing data, with a view to understanding the dynamics of land use and land cover changes from 1987 to 2011 in the district.

MATERIALS AND METHODS

Description of the study area

The study was conducted in the semi-arid rangelands of Taveta District bordered by Tsavo-West National Park to the east, Kenya - Tanzania border to the west and south Kajiado district to the north. The District covers an area of 645.4 km^2 and is located between longitudes 37° 25' E and 38° 17' E, latitudes 3° 15' S and 3° 62' S (Figure 1).

The mean annual rainfall ranges from 200 mm towards the Tsavo West National Park and increases gradually to about 800 mm towards the foothills of Mt. Kilimanjaro. The long rains fall between March and May while the short rains fall between November and December. The District is largely a dry area unsuitable for agriculture except the area towards Mt. Kilimanjaro and the lowlands under irrigation. Temperature ranges from 21.2 to 31.0°C (Jaetzold and Schmidt, 2005). The population growth rate of the District is high, standing at 2.94% (Republic of Kenya, 2009). Historically, the area was occupied by pastoral Maasai, however currently the population is multi-ethnic composed of people from other parts of Kenya and the Pare from Tanzania. The immigrants mainly engage in crop production. The pastoral Maasai's and Pare communities have also changed their lifestyle and are now currently engaged in agro-pastoralism. The area serves as a dispersal area for wildlife from Tsavo West National Park. Among the key conflict causing species found in the Tsavo West National Taveta district include elephants, primates, bushpigs, hippopotamus and buffalos.

Land use and land cover changes analysis

Satellite images were analysed in conjunction with ground truthing observations as proposed by Chakraborty (2001). Using a Global Positioning System (GPS), points corresponding to the various land uses and land cover forms where recorded as forest, rainfed agriculture, irrigated agriculture, shrublands, woodlands, sisal plantations and water bodies. Jenson (1986) recommends the use of at least two time-period data sets to detect changes in land use and land cover. 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 1987, 2001 and 2011 respectively were analysed. The images were downloaded from USGS Global Visualization Viewer (GLOVIS, URL: http://glovis.usgs.gov). Two of the images used in the analysis (1987 and 2011) were for the month of February while the 2011 image was for early March. Both time periods coincide with the dry season to avoid uncertainties.

Image classification

Land use and land cover maps where 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. Mahalanobis distance classification methods were used to classify the images (ESRI, 2009). Seven land use and land cover types were classified according to Andersen (1998) guidelines as forests, irrigated agriculture, rainfed agriculture, woodlands, shrublands, sisal plantations and water bodies.

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 (1987 and 2001 images, 2001 and 2011 images).

Human population trends

Human demographic data spanning from 1969 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
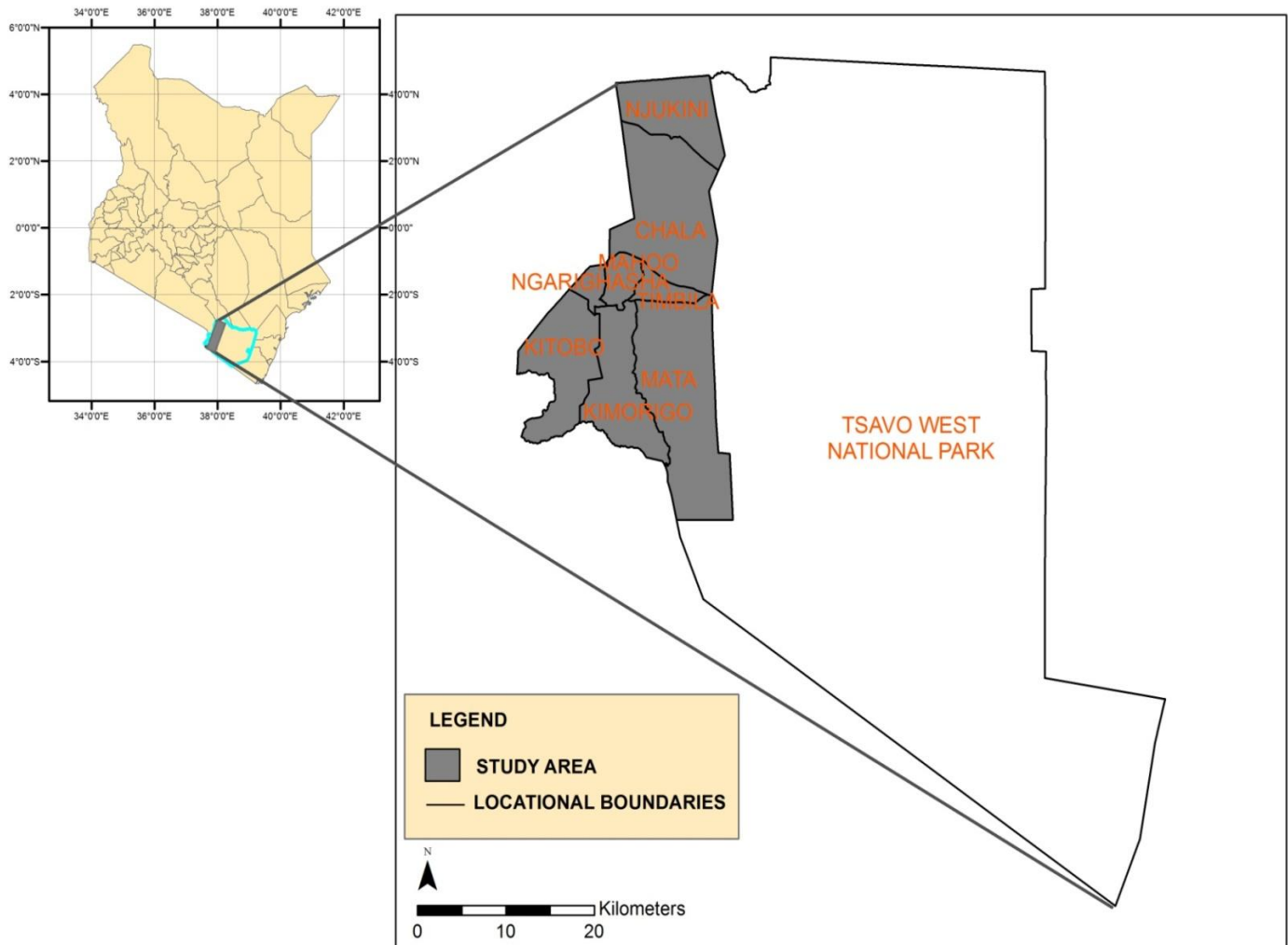
Figure 1. Map of Kenya showing the study area.

use and land cover change data to establish if there was any relationship between land use change and human population trends.

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. Overall land use and cover changes were calculated from the 1987and 2011 statistics. Chi-square goodness of fit was used to determine if there were significant changes in land use and land cover (Zar, 1996). Linear regression was used to show the relationship between land use change and human population growth with time (Zar, 1996).

RESULTS

Land use and cover changes between 1987 and 2011

Seven land use and land cover types and their dynamics were discriminated as forests, irrigated agriculture,

rainfed agriculture, shrublands, woodlands, sisal plantations and water bodies as shown in the classified land use and land cover maps below (Figures 2). By 1987, irrigated agriculture was confined to the far eastern part of the district from where it has continued to expand replacing forests. The most drastic expansion occurred between 2001 and 2011. Wildlife habitats mainly woodlands and shrublands decreased throughout the period of the study in favour of agricultural expansion by 54.54 and 17.14% respectively.

The area of each land use and land cover class for the three time periods and their percentage changes are as shown in Table 1. Between 1987 and 2001, major changes were observed mainly in forests, irrigated agriculture, woodlands and water bodies. In the subsequent time period (2001 to 2011), these land uses except the woodlands experienced again major changes in addition to sisal plantations. While forest cover increased by 117.2% by 2001, it decreased by 58.9% by the year 2011. The overall change in forest cover between the
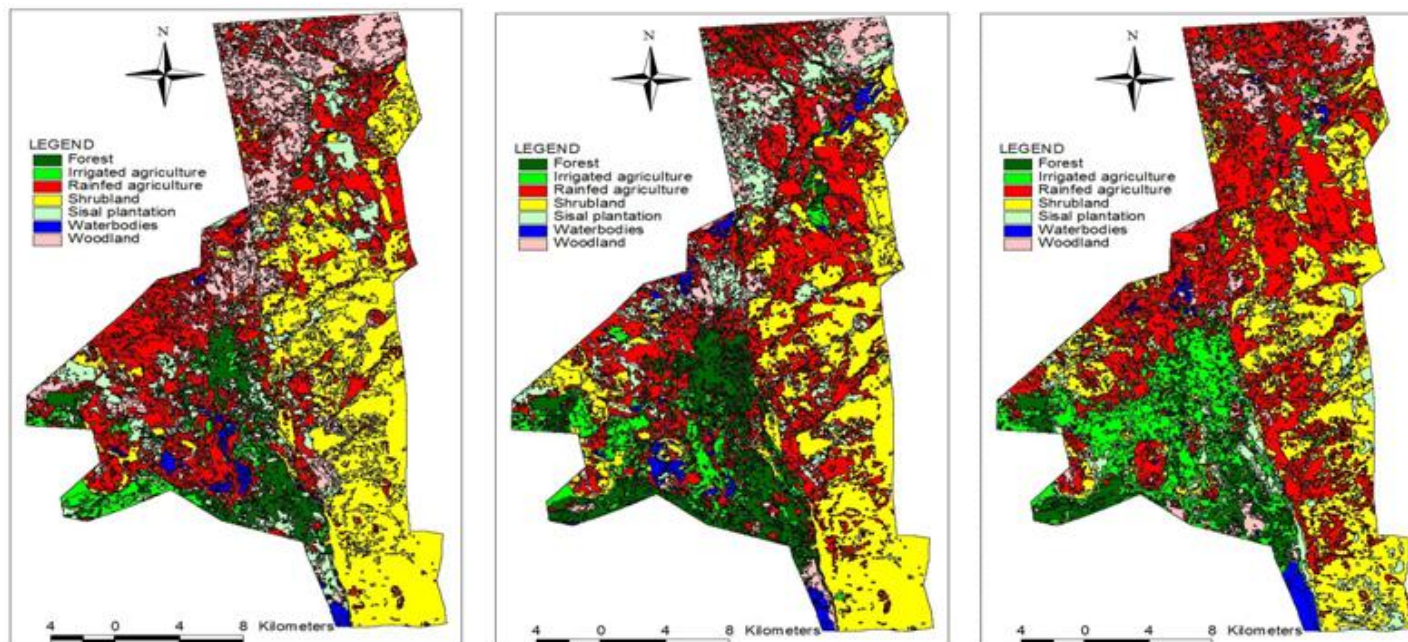
Figure 2. Land use and land cover changes for the years 1987, 2001, and 2011 as a, b, and c respectively.

three time periods was a 10.69% decrease. Compared to all the other land use and land cover types, forest cover showed the least overall changes. The area under woodland cover experienced a 58.2% decrease by 2001, and an 8.7% gain by 2011. The overall change was however a decrease by 54.6%. The area under cultivation increased over the three time periods by 299.4%, with irrigated agriculture contributing 268.6%. Sisal plantations decreased by 50.2% overall, especially between 2001 and 2011. Water bodies showed the second least overall changes with an increase of 18.9%. The decrease in woodland and shrublands occurred mainly between 1987 and 2001, while water bodies, sisal plantations and forests decreased mainly between 2001 and 2011, a time during which both forms of agriculture experienced the highest levels of increase. The most significant changes ($p = 0.001$) were observed in irrigated agriculture, sisal plantations and woodlands. Likewise, rainfed agriculture followed with a significant increase. Decrease in shrublands cover, water bodies and forests were not 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 four time periods, a sharp increase occurred between 1989 and 1999 compared to all other time periods. Overall, the study area has a population growth rate of 2.94% p.a and a population

density of 104.5 individuals per km^2 (Republic of Kenya, 2009).

DISCUSSION AND CONCLUSION

Satellite image analyses showed that land use and land cover changes have occurred in the study area between 1987 and 2011. Wildlife and livestock habitats especially woodlands, shrublands and forests were mainly converted to rainfed and irrigated agriculture. Although forests did not change significantly for the period under observation, it was observed that the area under forests expanded in the first 14 years. This was mainly as a result of invasion by *Prosopis juliflora,* planting of exotic trees and horticultural expansion mainly large scale establishment of mango (*Mangifera indica*) plantations. These results point to similar studies in Kenya; for example, Kioko and Okello (2010) studying land use cover and environmental change in the semi-arid Amboseli ecosystem observed concurrent changes within a period of 30 years (1976 to 2007), that is, the extend of land under both irrigated and rainfed agriculture increased significantly while riverine vegetation and perennial swamps decreased significantly as well.

Land use and land cover changes in this district have been occasioned by the increased demand for land resources for development and agri-cultural activities, infrastructural improvement, population increase and land ownership. The expansion of irrigated agriculture has been attributed to recurrent rainfall failure (Republic of

Table 1. Land use cover change (Km^2) in Taveta District between 1987 and 2011.

Land use / Land cover	1987		2001		2011		Change (1987-2001)		Change (2001-2011)		Overall change (1987-2011)	
	Area (Km^2)	% Area	Area (Km^2)	% Area	Area (Km^2)	% Area	Area (Km^2)	%	Area (Km^2)	%	Area (Km^2)	%
Forest	38.06	5.85	82.67	12.7	34	5.23	44.6	117.2	-48.7	-58.88	-4.07	-10.69
Woodland	96.23	14.8	40.23	6.19	43.72	6.72	-56	-58.2	3.48	+8.66	-52.52	-54.57
Shrublands	215.61	33.16	179.39	27.60	178.66	27.5	-36.2	-16.8	-0.73	-0.41	-36.95	-17.14
Rainfed agriculture	191.26	29.42	213.74	32.9	250.16	38.5	22.49	11.76	36.41	+17.04	58.9	+30.8
Irrigated agriculture	25.84	3.97	44.94	6.91	95.25	14.7	19.09	73.89	50.32	+111.97	69.41	+268.6
Sisal plantations	73.09	11.24	73.2	11.3	36.41	5.6	0.11	0.15	-36.8	-50.26	-36.68	-50.19
Water bodies	10.1	1.55	16.03	2.47	12.01	1.85	5.93	58.69	-4.02	-25.09	1.91	18.87

Table 2. Chi-Square goodness of fit test for the various land use /land cover changes in Taveta district between 1987 and 2011.

Land cover type	1987 (km^2)	2001 (km^2)	2011 (km^2)	% change in land use cover	χ^2 Goodness of fit test
Forest	38.06	82.67	34	-10.69	$\chi^2 = 0.359$, df = 2, p=0.836
Woodland	96.23	40.23	43.72	-54.57	$\chi^2 = 32.533$, df = 2, p=0.001
Shrubland	215.61	179.39	178.66	-17.14	$\chi^2 = 4.770$, df = 2, p=0.092
Rainfed agriculture	191.26	213.74	250.16	30.8	$\chi^2 = 8.101$, df = 2, p=0.015
Irrigated agriculture	25.84	44.94	95.25	268.6	$\chi^2 = 45.916$, df = 2, p=0.001
Sisal plantations	73.09	73.2	36.41	-50.19	$\chi^2 = 15.044$, df = 2, p=0.001
Water bodies	10.1	16.03	12.01	18.87	$\chi^2 = 1.474$, df = 2, p=0.479

Kenya, 2011), commercialization of agriculture and the demand for food resources occasioned by population increase. In previous studies, agriculture has been described as a major driver of forest loss. For example; Mwavu and Witkowski (2008) working in areas around Budongo forest in Uganda observed that the major land cover conversions were from forests/woodlands to sugarcane plantations, settlement and shifting cultivation. Studies by Campbell et al., 2003; Campbell 1993; Geist and Lambin (2002), MEA (2005a, b), Alejandro et al. (2007) and Kathumo (2011) indicate that agricultural expansion has been associated with deforestation in Asia, Africa and Latin America.

The drastic expansion of irrigated agriculture is also attributed to the fact that the preceding time period of 1989 to1999 was characterized by the highest population increase in the district and later by infrastructural improvement with the completion of the Emali - Oloitoktok road. This facilitated easy access to agricultural produce markets in Mombasa and Nairobi cities as well as Emali town thus driving agricultural expansion. Similar observations were made by Baaru (2011) in Kathekakai in Machakos district where, between 1988 to 2009, land use and cover changes were found to be influenced by human population increase, infrastructure and proximity to Nairobi city and Machakos town.

There appears to be a relationship between land use change and human population growth dynamics in Taveta district. The time period coinciding with the highest population increase (1989 to 1999) also coincides with the highest decrease in woodlands and shrublands and a corresponding increase in human dominated activities of agriculture as the area under water bodies expanded due to establishment of large aquaculture ponds. This was followed by an increase of both irrigated and rainfed agriculture between 2001 and 2011, leading t o decline of
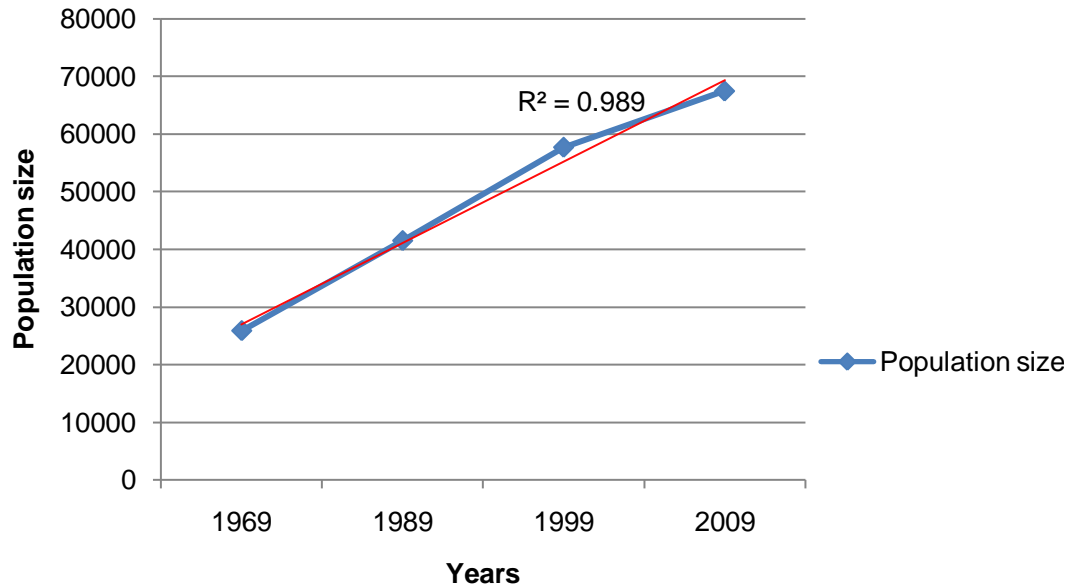
Figure 3. Human population trends in Taveta District between 1969 to 2009. Compiled from Kenya National Bureau of Statistics (KNBS).

shrublands and woodlands and more so in the northern part of the district which is also a wildlife corridor.

Land use changes in this wildlife dispersal area could have far reaching implications in terms of wildlife conservation. Having reduced the extend of wildlife habitats, land use change will likely affect species from Tsavo West National Park especially those that have large home ranges (e.g. elephants) as well as influence their migration by blocking migratory corridors. Elephants are known to migrate yearly from Tsavo West National Park to Tanzania through the northern part of the district, which is currently intensively cultivated. As a result, local communities within this area are experiencing intensified human-wildlife conflicts occasioned by blockage of this elephant migratory corridor. Changes in land use patterns are known to influence local community's opinion on wildlife and their conservation due to the impacts experienced (Okello, 2005; Kioko and Okello, 2010). The land use change patterns observed in Taveta district, where agricultural expansion is high; will most likely have an impact on local community's view for wildlife and its conservation since most of the local communities are dependent mainly on agriculture and livestock for their livelihoods. Considering the current status of human-wildlife conflicts in the district, wildlife will have to pay for utilizing such human dominated landscapes to compensate for and enhance community tolerance. For example, in similar experiences observed within the Amboseli area of Kajiado district by Okello and Kioko (2010) while studying land use change and human-wildlife conflicts, they found that, support for free-roaming wildlife was dependent on type of land use practiced and the type of species causing livestock depredation. In addition,

appreciation for wildlife resources was dependent on whether significant benefits from wildlife resources or wildlife related tourism were obtained.

Considering that Kenya's population growth is high and that the global human population is projected to reach nine billion by 2050, a nearly two billion person increase from current estimates (UN, 2009), it is expected that more challenges will be experienced in natural resource management in rangelands especially due to immigrants mainly from densely populated areas, and for commercial agricultural expansion in Kenya.

Being a dispersal area, there is need for a scientifically-based land use planning and selection of suitable land use options to balance human needs and conservation goals in this landscape. This will also serve to counteract possible land resource degradation and mitigate human-wildlife conflicts. Land use planning ought to employ the ecosystem approach and aim at establishing a "Zone of Interaction" which caters for local community and wildlife needs within this district. This will require the participation of the relevant stakeholders including local communities as custodians of the land, and involve targeting locations and processes of particular importance that enhance community livelihood at the same time the ecological integrity of the adjacent Tsavo West National Park. Such ventures will include delineating the migratory corridors, catchments of rivers and streams such as Kitobo, Njoro, Tsavo and Lumi rivers which are important for local community and wildlife survival. Wildlife migratory corridors will need to be protected and monitored to allow wildlife migration especially elephants and reduce conflicts in the face of increasing human population. It is also necessary to establish community knowledge and

awareness on the links between resource change dynamics and their implications. This will be necessary to facilitate development of strategies for their participation and land use planning that balances local community restrictions on land use and community needs while maintaining the ecological integrity of the landscape.

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