International Journal of Ecology and Environmental Sciences 46 (2): 177-186, 2020
ISSN: 0377-015X (Print); 2320-5199 (Online)

Appraisal of Land Use Transformation using Remote Sensing in Kajiado County, Kenya

James Kaoga[1*], Daniel Olago[2] , George Ouma[3], Gilbert Ouma[4] and Joshua Onono[5]

1. University of Nairobi, Climate Change and Adaptation, P.O. Box 30197-00100, Nairobi, Kenya
2. College of Biological and Physical Sciences, P.O. Box 30197-00100, Nairobi, Kenya.
3. Jaramogi Oginga Odinga University of Science and Technology, P.O. Box 210-40601 Bondo, Kenya.
4. College of Biological and Physical Sciences, P.O. Box 30197-00100, Nairobi, Kenya.
5. College of Agriculture and Veterinary Sciences, P.O. Box 29053-00625, Nairobi, Kenya.
Emails: [1]jameskaoga@gmail.com; [2]dolago@uonbi.ac.ke ; [3]goumaoindo@yahoo.com; [4]gouma@uonbi.ac.ke; [5]joshua.orungo@uonbi.ac.ke
*Corresponding author

ABSTRACT

Kajiado County is predominantly inhabited by the Maasai nomadic pastoralists who rely on natural systems for their provisions and production needs. Traditionally, communal land management has been the norm in the area but that has evolved under the swift development context with the private holding of land becoming prevalent. The land-use transformation has curtailed the traditional seasonal movement of livestock and that has exposed the Maasai community to production risks which have contributed to the widespread food insecurity in the area. To address this gap, the study investigated land-use transformation in the area using Landsat 8, 4 and 5 datasets, where 1987, 2000 and 2015 epochs with a spatial resolution of 30*30m were sourced from www.glovis.usgs.org Remote sensing technology used to evaluate biophysical attributes showed changes in land-use patterns with the bare area, built-up area, cropland, forested land, grassland, riverine, shrubland, waterbody and wetland having undergone significant changes in their respective sizes. These land-use transformations have been compounded with the spread of invasive species to the point of threatening pastoralism. However, the successive governments have shown a marked disdain for resource use patterns. Thus, there is need for an all-inclusive land-use policies to inform adaptation and resilience planning in Kajiado County, Kenya.

Key Words: Natural Resource; Pastoralism; Biophysical Attributes, Land-Use Transformation; Remote Sensing

INTRODUCTION

Globally, pastoralists are known to inhabit the Arid and Semi-Arid Lands (ASALs) which are characterized as hostile and less productive (McCabe 2003). In Kenya, ASALs occupy 80 per cent of the landmass and it is home to about 20-25 per cent of the country's population (ILRI 2006). Kajiado County is one of the 27 ASAL counties in Kenya (MOALF 2017). The Maasai pastoralists, who are the dominant tribe, derive their livelihood from livestock rearing (Watson et al. 2016) which creates a delicate balance between the available natural resources and optimal livestock density in that complex ecosystem (Nori 2007).

The communal land system has aided them secure large herds. However, the significant conversion of communal to private landholdings is raising concerns over the future of pastoral livelihood system considering that large tracts of land under communal use still unregistered. There is an emerging trend of private landholding which continues to thrive on the basis of the weak land tenure but it is a disjuncture to nomadic pastoralism. The overlaps in territorial claims has made the community to continue losing their grazing area from private holders leading to dispossession of their customary land and as such their traditions could easily become obsolete (Ng'ang'a et al. 2016).

The growing pressure for land subdivision is disrupting the natural system and that has left the Maasai pastoralists with multiple production risks (Folk et al. 2010). The altered land-use patterns has curtailed their mobility (Cuni-Sanchez et al. 2016) as manifested in the herd losses (Walker et al. 2004, Roth et al. 2012 and Ng'ang'a et al. 2016) because the Maasai pastoralists rely on natural systems for their provisions and production needs (Watson et al. 2016, Carley et al. 2013). Therefore, Maasai pastoralists have increasingly become vulnerable and locked in spiral chronic food insecurity and poverty. This prompted the need for an in-depth study to offset the incomplete understanding of the status of natural resources in relation to the pastoral livelihood system. Thus, the study evaluated the status of biophysical attributes since the Maasai pastoralists derive their ecosystem services from nature (Homewood et al. 2012).

The Maasai community harbours a rich indigenous knowledge which has thrived over time. This knowledge has helped them to be resilient and to sustain their ecology (OleSaitabau 2014) fostered by the good relations and complex system of exchange of knowledge (Ngong et al. 2007). The Maasai pastoralists have strong conservation values especially when it comes indigenous tree species such as Juniperus procera, Olea europacea and Cuspidatus spp which are conspicuous in the area. It is important to note that these trees have accrued benefits which include: provision of herbal medicines, treatment extracts and other unique spices Nahlik et al. (2012). Furthermore, the assemblage of wild herbivores in the area have attracted revenue, albeit indirectly, as tourism ventures extend goodwill by helping in the conservation efforts of the Maasai pastoralists and it also complements the income of the pastoralists (Burn silver et al. 2003).

METHODS AND MATERIALS

The Study Area

Kajiado County is located in the southern region of Kenya bordering five counties, namely: Nairobi, Machakos, Makueni, Taita Taveta and Nakuru counties. The County also borders Tanzania where it shares a section of Mt. Kilimanjaro in Loitokitok area. The County's average area is 21,900.9 km^2 and lies between latitudes 1° 0′ and 3° 0′ S and longitude 36° 5′ and 37° 5′ E (Figure 1). The County's altitude ranges between 1580 and 2460 metres above sea level (GoK 2016) and it is predominantly occupied by the Maasai pastoralists (Mworia and Kinyamario 2008). The main economic activity is livestock rearing that highly depends on natural vegetation (Reynolds et al. 2007). The population of Kajiado County has grown significantly in the last 30 years from a population of 258,659 in 1989 to 1,111,840 in 2019 (KNBS 2019).

Land Use Land Cover Mapping

Remote sensing technology was applied where Landsat datasets were used to develop land cover maps for the years 1987, 2000 and 2015. These quantitative satellite datasets were sourced from www.glovis.usgs.org and are available as open data portal. The land use land

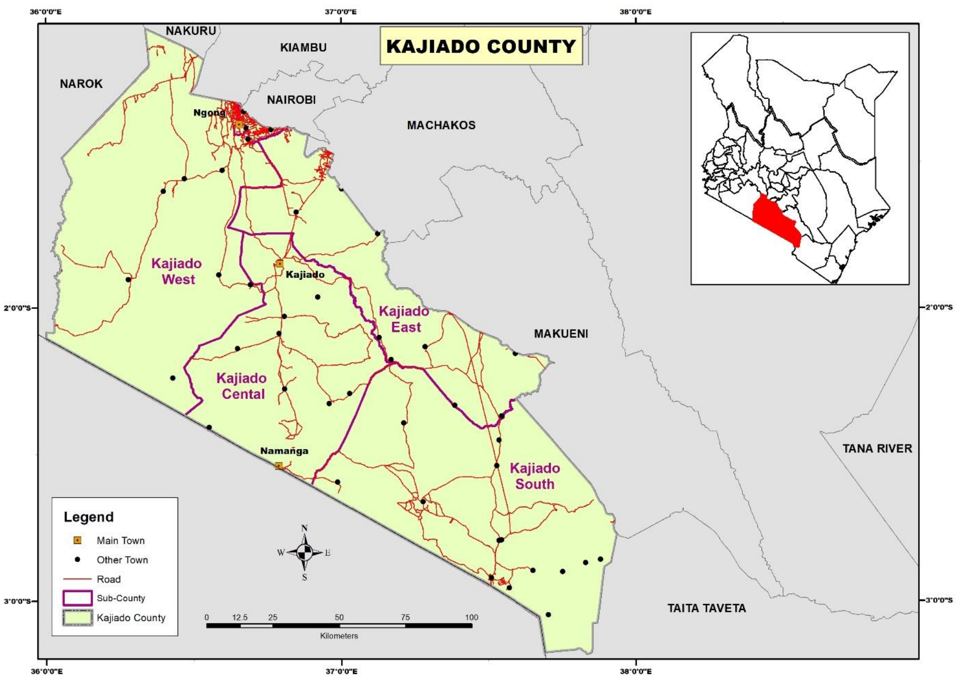

Figure 1. Map of Kajiado County showing administrative boundaries

cover mapping sought to determine land cover changes that had taken place over time to evaluate the status of biophysical attributes in the County.

Remote sensing and GIS technique are essential for mapping as it enables fieldwork covering larger areas to be completed at a lower cost and more quickly (Barret and Curtis, 1982). According to Shuckman et al. (1987), remote sensing is the science of deriving information about the Earth features from images acquired at a distance while relying upon measurements of electromagnetic energy reflected or emitted from the feature of interest.

The entire mapping development process is shown in Figure 2.

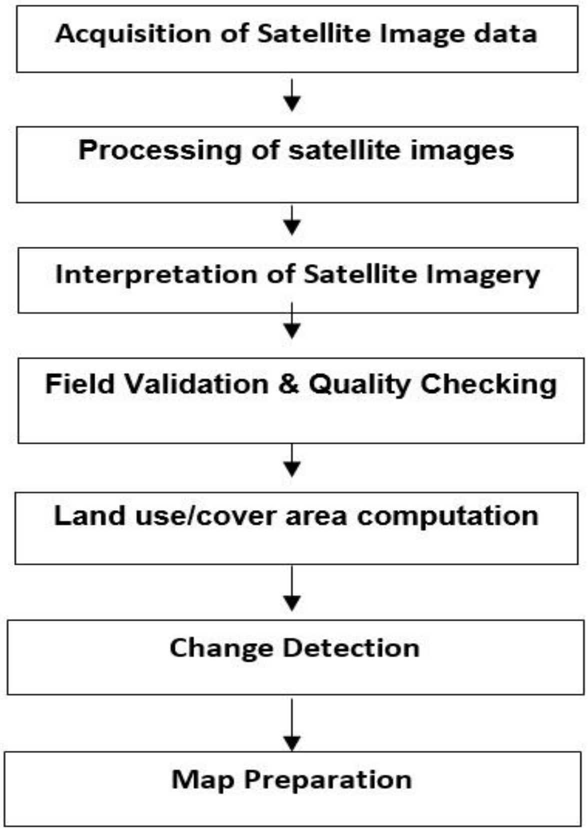

Figure 2. Flow chart on LULC mapping development process

Acquisition of satellite images

Remote sensing and GIS technique were used to analyse historical land use/ land cover which included vegetated areas and artificial surfaces (Barret and Curtis 1982). These consisted of Landsat 8, 4 and 5, where 1987, 2000 and 2015 epochs with a spatial resolution of 30m were sourced from www.glovis.usgs.org while focussing on the dry season imagery (cloud-free) i.e. January-March and July-September (Tiwari and Saxena 2011).

Processing of satellite images

The raster form of datasets for 1987 2000 and 2015 epochs underwent pixel-based screen supervised classification (Barret and Curtis, 1982). The classified data produced were edited using both interactive and batch mode. This process encompassed layer-stacking, subsetting and mosaicking using ArcGIS and impact tool (JRC[1]) (Barret and Curtis, 1982). The generated pre-processed database from which analysis was done utilised ancillary data in which case ILRI polygons with readily available shapefiles were used to derive control points such as roads, rivers and administration boundaries that were used to geo-reference the coordinates in the base maps.

Interpretation of satellite imagery

Image classification process involved identifying features on LULC maps through supervised classification maximum likelihood classifier (Enderle and Weihjr 2005) methodology in ENVI software platform from which each of the period image with nine land-use classes identified based on the Food and Agriculture Organisation (FAO) Land Cover Classification System (LCCS) was adopted. The major land cover types were: bare area, built-up area, cropland, forestland, grassland, riverine, shrubland, waterbody and wetland.

Validation and quality checking

The validation of the output of the land cover was done before the final interpretations. The first draft of images generated were further analysed and it involved field checks which further confirmed the identified land cover categories latent to the Landsat imagery. This was carried out according to Lillesand et al. (1994) where validation targeted specific parts of interest which were cross-checked using high-resolution imagery from Google Earth to verify accuracy of the maps and aid in further identification of doubtful cases marked during interpretation Figure 3.

Table 1 shows accuracy which was utilised and it gives an indication of the quality of map based on areas of interest. The overall accuracy is essential as it tells us the proportions that are correctly mapped out of the reference sites which are expressed in percentages. In this regard, the study has attained an accuracy level of 80.16% with 100 % accuracy being a perfect classification.

Joint Research Centre is a research-based policy support organisation and an integral part of the European Commission

Figure 3. Google Earth image showing biophysical features on a section of the study area

Table 1: Summary of Internal Validation for the LULC

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Forestland	24	16	9	37.50%	56.25%
Shrubland	214	198	181	84.58%	91.41%
Grassland	13	37	10	76.92%	27.03%
Cropland	3	3	3	100.00%	100.00%
Wetland	2	2	2	100.00%	100.00%
Built area	1	1	1	100.00%	100.00%

Overall classification accuracy = 80.16%

Data Analysis

The analyses of data commenced once editing, coding, classification and tabulation of the raw data had been completed. Statistical software tools ArcGIS was used at various points for analyses of satellite data to establish land cover changes in the form of area computation based on the land cover maps by cross-referencing the different years to detect noticeable changes.

The resulting maps which included 1987, 2000 and 2015 were imported and overlaid into ArcGIS software for analysis while factoring in the main land cover classes. The maps were compared and manipulated through overlays to extract the total areas under the nine land cover types and quantify the LULC changes in hectares.

Further, the rate of change per year was calculated using the formula:

$R= \quad R=\frac{Y-X}{T}$ ...Equation 1

Where:

R is the rate of change

Y is the area in hectares of the study area in the final year

X is the area in hectares of the study area in the initial year

T is the difference in years.

The percentage rate of changes for the various land use covers were calculated by dividing the rate of change per year by the original areas respectively for change detections.

RESULTS

The Landsat satellite datasets were used to generate Land Use Land Cover maps for the years 1987, 2000 and 2015 (Figures 4, 5 and 6). These maps were subjected to validation using simple points collected from high-resolution images from Google Earth as ground truth data. The maps were the output of spatial data and were visually represented on based on the Food and Agriculture Organization Land Cover Classification System (FAOLCCS) covering the nine Land Use Land Cover (LULC) types across the entire Kajiado County.

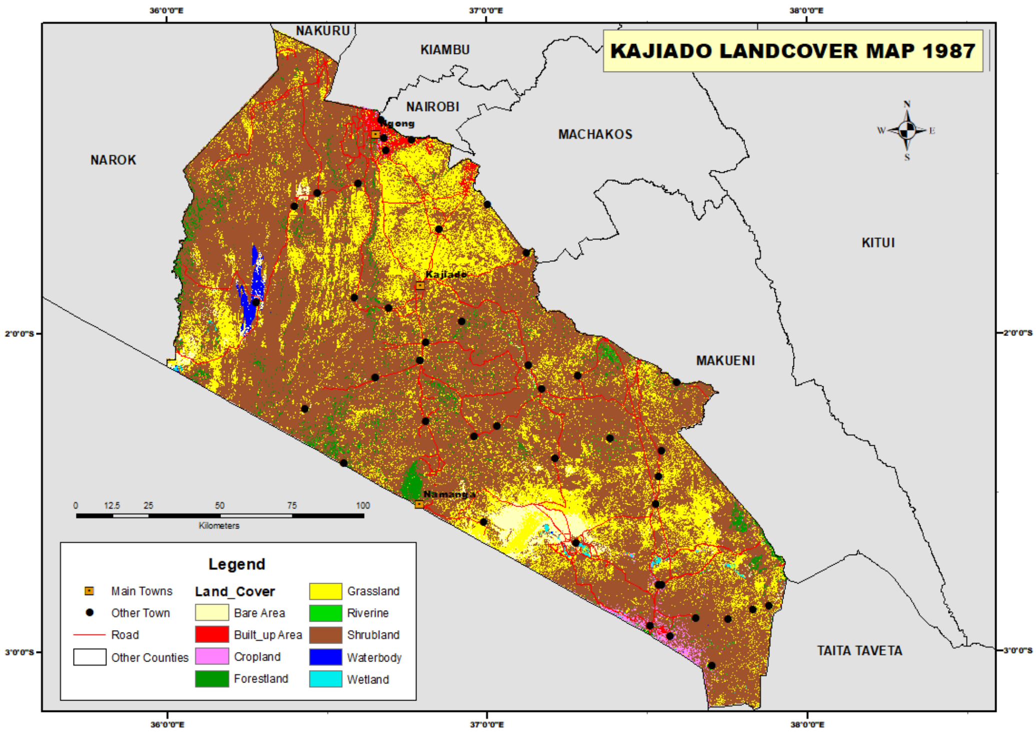

Figure 4. Kajiado County Land Cover Map 1987 (Data source: www.glovis.usgs.org)

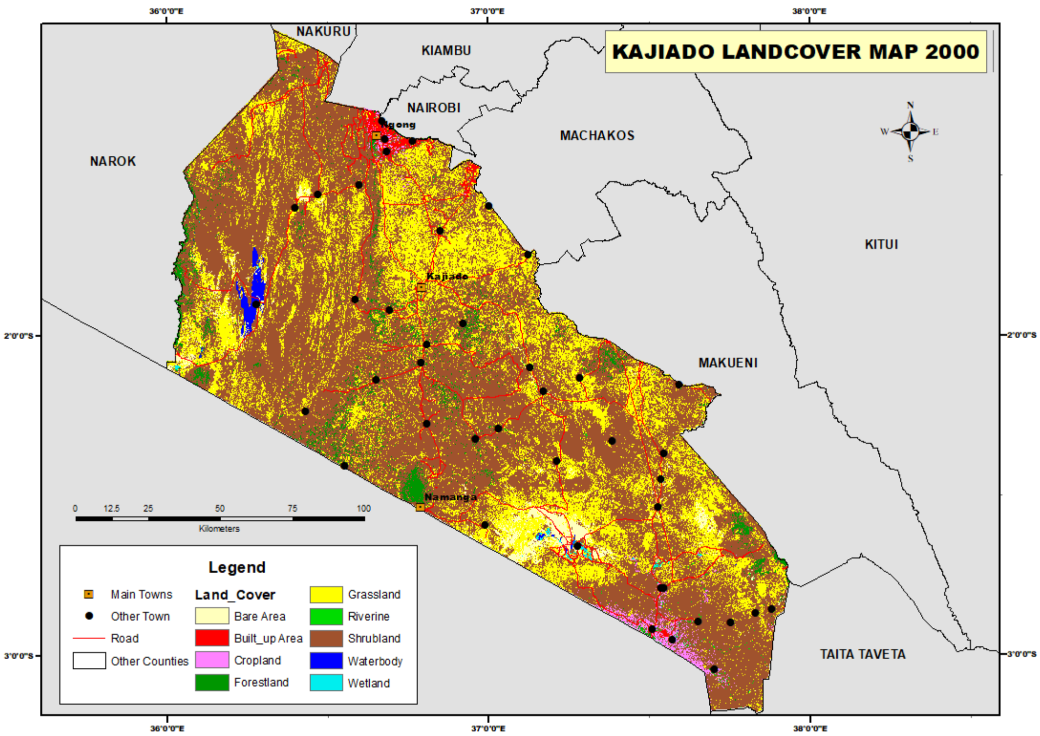

Figure 5. Kajiado County Land Cover Map 2000 (Data source: www.glovis.usgs.org)

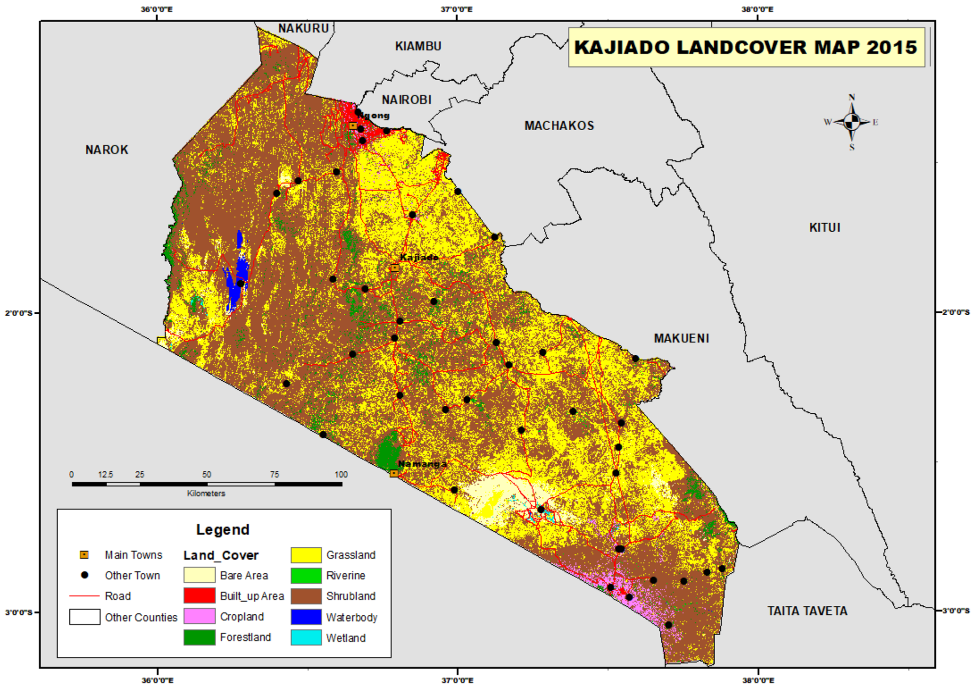

Figure 6. Kajiado County Land Cover Map 2015 (Data source: www.glovis.usgs.org)

Land Use Land Cover Mapping

Statistics for Land Use Land Cover in Kajiado County

Statistics were generated based on the three maps (Figures 4 to 6) where the area of Land Use Land Cover changes were established by cross-referencing the different years of land covers covering changes between 1987 and 2000, 2000 and 2015 and 1987 and 2015.

The results of the summarized statistics for Land Use Land Cover Mapping (Table 2).

The results using 1987 as the initial year (past) and 2015 as the final year (near present) with the actual LULC change types computed in hectares (Table 3). The gains were in the bare area (1,387), built-up area (615), cropland (14,914), grassland (211,573) and forestland (9,870) and the loses were in riverine (-922), shrubland (-235,925) waterbody (-216) and wetland (-1,304).

The results using 1987 as the initial year and 2000 as the final year with the actual changes under the various LULC categories computed in hectares (Table 4). The gains were in the built-up area (346), cropland (8,614), grassland (129,952), forestland (4,015) and waterbody (1,307) and loses were in the bare area (-6,453), riverine (-2,715), shrub land (-134,141) and wetland (-862).

The results using 2000 as the initial year and 2015 as the final year, the actual changes under various LULC computed in hectares (Table 5). The gains were in the

Table 2. Statistic for Land Use Land Cover types in 1987, 2000, 2015

S/No.	LULC types	Area (hectares)		
		Year: 1987	Year: 2000	Year: 2015
1.	Bare area	55,130.31	48,676.95	56,517.48
2.	Built up area	326.88	672.66	942.12
3.	Cropland	15,382.80	23,997.24	30,295.89
4.	Forestland	55,371.96	59,386.56	65,242.08
5.	Grassland	480,015.81	609,967.98	691,588.80
6.	Riverine	9,292.50	6,578.19	8,370.18
7.	Shrubland	1,560,841.20	1,426,699.78	1,324,916.37
8.	Waterbody	9,862.20	11,169.99	9,646.47
9.	Wetland	3,848.94	2,987.10	2,544.84

Data source: www.glovis.usgs.org

Table 3. Land Use Land Cover changes from 1987 to 2015

S/No.	LULC types	Area (Hectares)		
		Year: 1987	Year: 2015	Change (1987-2015)
1.	Bare area	55,130	56,518	1,387
2.	Built up	327	942	615
3.	Cropland	15,383	30,296	14,914
4.	Forestland	55,372	65,242	9,870
5.	Grassland	480,016	691,589	211,573
6.	Riverine	9,293	8,370	-922
7.	Shrubland	1,560,841	1,324,916	-235,925
8.	Waterbody	9,862	9,647	-216
9.	Wetland	3,849	2,545	-1,304

Data source: www.glovis.usgs.org

Table 4. Land Use Land Cover changes from 1987 to 2000

S/No	LULC types	Area (Hectares)		
		Year: 1987	Year: 2000	Change (1987 to 2000)
1.	Bare area	55,130	48,677	-6,453
2.	Built up area	327	673	346
3.	Cropland	15,383	23,997	8,614
4.	Forestland	55,372	59,387	4,015
5.	Grassland	480,016	609,968	129,952
6.	Riverine	9,293	6,578	-2,715
7.	Shrubland	1,560,841	1,426,700	-134,141
8.	Waterbody	9,862	11,170	1,308
9.	Wetland	3,849	2,987	-862

Data source: www.glovis.usgs.org

Table 5. Land Use Land Cover changes from 2000 to 2015

S/No.	LULC types	Area (Hectares)		
		Year: 2000	Year: 2015	Change (2000-2015)
1.	Bare area	48,677	56,518	7,841
2.	Built up area	673	942	269
3.	Cropland	23,997	30,296	6,299
4.	Forestland	59,387	65,242	5,855
5.	Grassland	609,968	691,589	81,621
6.	Riverine	6,578	8,370	1,792
7.	Shrubland	1,426,700	1,324,916	-101,784
8.	Waterbody	11,170	9,647	-1,523
9.	Wetland	2,987	2,545	-442

Data source: www.glovis.usgs.org

bare area (7,841), built-up area (269), cropland (6,299), grassland (81,621), forestland (5,855) and riverine (1,792) and loses were in the shrubland (-101,784) waterbody (-1,523) and wetland (-442).

The results of changes in the area when the study period was split into two equal intervals between the early years (from 1987-2000 period) and later years (from 2000-2015 period). There were relative changes in the magnitude at which land use transformation was taking place from the areas under the various LULC types (Table 6). The results showed relatively less changes in the status of the bare area, forestland and waterbody and more changes in the status of built-up areas, cropland, grassland, shrubland and wetland in the early years (from 1987-2000 period) compared later years (from 2000 to 2015 period).

LULC rate of change per annum

The results based on the percentage rate of change for the three periods namely 1987 to 2000, 2000 to 2015 and 1987 to 2015 (Table 7).

Table 6. Land Use Land Cover change comparison in hectares between the early (1987-2000) and later (2000-2015) Period

S/No.	LULC Types	Change of Area (Hectares)	
		(1987-2000)	(2000-2015)
1.	Bare area	6,453	7,841
2.	Built up area	346	269
3.	Cropland	8,614	6,299
4.	Forestland	4,015	5,855
5.	Grassland	129,952	81,621
6.	Riverine	2,714	1,792
7.	Shrubland	134,141	101,784
8.	Waterbody	1,308	1,523
9.	Wetland	1,524	442

Data source: www.glovis.usgs.org

Table 7: Percentage rate of change (type per annum) (Data source: www.glovis.usgs.org)

S. No.	LULC Types	Percentage rate of change (ha/annum)		
		1987-2000	**2000-2015**	**1987-2015**
1.	Bare area	-0.90	1.07	0.09
2.	Built up	0.08	2.67	6.72
3.	Cropland	0.04	1.75	3.46
4.	Forestland	0.01	0.66	0.64
5.	Grassland	0.02	0.89	1.57
6.	Riverine	0.02	1.82	-0.35
7.	Shrubland	0.06	-0.48	-0.54
8.	Water body	0.01	-0.91	-0.08
9.	Wetland	0.02	-0.99	-1.21

Positive sign (+) means increase and a negative sign (-)means a decrease in area

DISCUSSION

The Land Use Land Cover mappings covering the years 1987, 2000 and 2015 highlighted key land classification clusters in Kajiado County namely: bare area, built-up area, cropland, forestland, grassland, riverine, shrubland, waterbody and wetland. This observation is similar to those of Niamey and Fuller (2000); Gunderson and Holing (2002) and Homewood et al. (2012) who reported that the County is endowed with vast species. The results of Land Use Land Cover mapping indicated that the forestland had increased progressively which is attributed to the communal land ownership and traditional stewardship structure which has largely supported the livestock production system in Kajiado County. However, the study established the growth of private landholdings with the expanding alternative land uses such as built-up areas and cropland. This observation is in agreement with that of Lalisa (2015) who noted the expansion of settlement and cropland. According to Catley et al. (2013), this is associated with exclusivity in land use which is a threat to the pastoral Social-Ecological System which if left uncontrolled could adversely affect pastoralism. Similarly, Carley et al. (2013) and Schwartz (2005) noted that significant areas of the habitat has been converted for alternative land-uses which is a threat to pastoralism and recipe for environmental degradation. Birch and Grahn (2007) reported that alternative land uses have created discord, promoted exclusivity and as such, increased production risks.

The noticeable loses in riverine, wetland and waterbody were connected in one way or another to the changes in the land-use patterns. This observation is similar to that of Galvin et al. (2004) who noted increased encroachment in riparian areas which he attributed to irrigated agriculture and preference of urban centre encroachment in locations closer to water sources. The land-use policy bottleneck has also contributed to the receding water levels which is detrimental to the pastoralism and could negatively affect livestock production (Juma 2009 and Watson et al. 2016). According to Chibinga (2010) and Waila et al. (2018), most policies are biased towards sedentary crop production. Moreover, laws to secure community land rights of the Maasai Pastoralists have been slow or often manipulated leaving them out in development debate on issues touching on their environment and economic livelihood (Mutu 2017). Moreover, their conservation efforts have been frustrated.

The Maasai pastoralists have ended up with multiple production risks which they might not be able to tackle on their own in the fast-changing context of land-use transformation. In as much as grassland areas appeared to have increased from the land use land cover mappings, it is important to note that its interpolation with invasive species such as Prosopis Julisflora and Ipomoea spp complicated the dynamics in this ecosystem. Invasive species are known to suppress the indigenous and palatable grass species. This observation is similar to that of Kidake et al. (2016) who reported a significant spread of invasive species of up to 60-80 per cent in the pasture fields in the area. As such, this has eroded the Maasai pastoralists'ability and rendered sustainable pastoralism unattainable. Furthermore, the Maasai pastoralists have become less cohesive leading to the adoption of other forms of practices associated with land alienation and sedentary lifestyle. Filho et al.

(2017) opine that evolving cultural practices by a section of the community is linked to the distortions of norms and social networks. These sentiments concur with those of Kramer and Brewer's (1984) economic theory which states that "*where there is high competition for resources, social non-conformity dominates*".

CONCLUSIONS

The Maasai pastoralists are still connected with nature and through these connections they have been able to make deliberate actions to safeguard their ecosystem's capacity to maintain vast biodiversity. However, the fast rate at which the land-use is getting transformed could compromise their land management decisions which have remain misunderstood by outsiders who argue from the point of unknown. The outsiders view pastoral livelihood as backward and environmentally destructive. As such, the Maasai pastoralists have not gotten adequate support from the successive governments who have been biased towards sedentary agrarian-driven system. It is against this backdrop that the Maasai pastoralists have become more vulnerable as they have had limited access to critical resources.

RECOMMENDATION

The natural regeneration of resources in Kajiado County cannot be realizable with the current state of land policy bottlenecks. Thus, the study recommends policy realignment which should involve the existing local traditional institutions in the integration of livelihood protection and diversification.

ACKNOWLEDGEMENTS

I would also wish to express my gratitude to the Regional Centre for Mapping of Resource for Development (RCMRD) for their logistic and technical support. This work was supported by the National Council of Science and Technology (NACOSTI) under PhD Grant No. NACOSTI/RCD/ST&I/ 7TH CALL/PHD/066. Data on the status of land cover were sourced from the processed Landsat 8, 4 and 5 satellite imagery available as open source from www.glovis.usgs supported by National Aeronautics and Space Administration (NASA).

Authors' contributions: J. Kaoga was the team leader responsible for the dentification of study site, acquisition of datasets, application of computational data analysis, synthesis and writing up of original draft. D. Olago developed overarching research goals and conceptual framework. George Ouma designed the study and worked on field characteristics. Gilbert Ouma edited the manuscript and J. Onono evaluated the datasets.

Conflict of interest: We declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Bavikatte, K.S. and Bennett, T. 2015. Community Stewardship: Foundation of Bio-cultural Rights. Accessed on 29.03. 2015 from https://gnhre.orgcommunity-stewardship-the-foundation-of- bio-cultural-rights-Bavikatte and Bennett.

Barret, E.C. and Curtis, L.F. 1982. Introduction to Environmental Remote Sensing. Chapman and Hall, London 324 pages.

Birch, I. and Grahn, R. 2007. Pastoralism-Managing Multiple Stressor and the Threat of Climate Variability and Change. Human Development Report Office Occasional Papers (1992-2007) HDOCPA-2007-45, Human Development Report Office (HDRO), United Nations Development Programme (UNDP). Accessed on 11.11.2017 from http:// core.ac.uk/download/pdf/6248692pdf.

Bobadoye, A.O.; Ogara, W.O.; Ouma, G.O. and Onono, J.O. 2016. Assessing climate change adaptation strategies among rural Maasai pastoralists in Kenya. American Journal of Rural Development, 4(6): 120-128.

Burnsilver, S.B.; Boone, R.B. and Galvin, K.A. 2003. Linking Pastoralists to a Heterogeneous Landscape: The Case of Four Maasai Group Ranches in Kajiado District, Kenya pages 173-199, In: Fox, J.; Rindfuss, R.R.; Walsh, S.J. and Mishra, V. (Editors), People and Environment: Approaches for Linking Households and Community Surveys to Remote Sensing and GIS. Kluwer Academia Publisher, Boston, MA, USA.

Catley, A.; Scoones, I. and Lind, J. 2013. Pastoralism and Develop-ment in Africa: Dynamic Change at the Margins. Routledge and Earth Scan, London. 295 pages.

Chibinga, O.C.; Musimba, N.M.; Nyangito, M. and Simbaya, J. 2010. Climate Variability: Pastoralists' Perception, Practices and Enhancing Adaptive Pasture Use for Food Security in Choma District, Southern Zambia. University of Zambia, Great East Road Campus, School of Agricultural Sciences.

Cuni-Sanchez, A.; White, L.T.; Calders, K.; Jeffery, K, J, Abernethy, K.; Disney, M.; Gilpin, M.; Gomez-Dans, J.L. and Lewis.S.L. 2016. African Savanna-Forest Boundary Dynamics: 20 years Study. PloS One, 11(6): e0156934.http://doi.org/10.1371/journal.pone.0156934.

Filho, L.W.; Nzengya, D.; Muasya, G.; Chemuliti, J. and Kalungu, J.W. 2017. Climate Change Response among the Maasai Community in Kenya. Climatic Change 145(6). DOI: 10.1007/s10584-017-2087-9

Folke, C.; Carpenter, S. R.; Walker, B.; Scheffer, M.; Chapin, T. and Rockström, J. 2010. Resilience thinking: integrating resilience, adaptability and transformability. Ecology and Society 15(4): 20-29.

Galvin, K.A.; Thornton, P.K.; Boone, R.B. and Sunderland, J. 2004. Climate variability and impacts on East Africa livestock herders: the Maasai of Ngorongoro conservation area, Tanzania. Journal of Range and Forage Sciences 21: 183-189.

GoK. 2016. Kajiado County Statistical Abstract Government of

Kenya, Nairobi. Accessed on 1.11.2017 from https://books.google.co.ke/books/about/County_Statistical_Abstract_Kajiado_Coun.html?id=uPTPzAEACAAJ&redir_esc=y.

Gunderson, L. H and Holling, C.S. 2002 Panarchy: Understanding Transformations in Human and Natural Systems. Island Press. Washington D.C.; USA 507 pages.

Homewood, K.M. and Rodgers, W.A. 1991. The Maasailand Ecology: Pastoralist Development and Wildlife Conservation in Ngorongoro, Tanzania. Cambridge Studies in Applied Ecology and Resources Management, Cambridge University Press, Cambridge. Accessed on 13.11.2017 on http://books.google.co.ke

Homewood, K.; Trench, P. and Brockington, D. 2012. Pastoralist livelihood and wildlife revenue in East Africa: A case study of coexistence?. Pastoralism Research, Policy and Practice, 2 (19): 2041-7136.

ILRI (International Livestock Research Institute). 2006. Shapefiles of Ward Level: 4th Administrative Unit Census Data from ILRI Spatial Database. Nairobi, Kenya.

Juma, R.O. 2009. Turkana Livelihood Strategies and Adaptation to Drought in Kenya. PhD dissertation. Victoria University, Wellington.

KNBS (Kenya National Bureau of Statistics). 2019. Kenya Population and Housing Census. Nairobi, Kenya. Accessed on 2.1.2020 from https://africacheck.org/wp-content/uploads/2020/03/2019-KPHC-Volume-II_.pdf

Kidake, B.K.; Mayeki, J.K.; Kubasu, D. and Mnene, W.N. 2016. Promotion of range pasture and fodder production among the pastoral and agro-pastoral communities in Kenyan pastoralists: experiences and lessons learnt. Livestock Research for Rural Development, 28(8): 814-824.

Kramer, R.M. and Brewer, M.B. 1984. Effects of group identity on resource use in a simulated commons dilemma. Journal of Personality and Social Psychology, 46(5): 1044-1057.

Lillesand, T.M. and Kiefer, R.W. 1994. Remote sensing and image interpretation. Photogrammetric Engineering and Remote Sensing 60(4): 479-488.

Mapiye, C.; Foti, R.; Chikumba, N.; Poshiwa, X.; Mwale, M.; Chivuraise, C. and Mupangwa, J.F. 2006. Constraints to adoption of forage and browse legumes by smallholder dairy farmers in Zimbabwe. Livestock Research for Rural Development 18(12): 712-724

McCabe, J.T. 2003. Sustainability and Livelihood Diversification among the Maasai of Northern Tanzania, Human Organisation, 62:100-111.

MoALF (Ministry of Agriculture, Livestock and Fisheries). 2017. Climate Risk Profile for Kajiado County. Ministry of Agriculture, Livestock and Fisheries, Government of Kenya, Nairobi, Kenya. Accessed on 4.11.2018 from http://www.nafis.go.ke/wp-content/uploads/2018/02/Programme-Document-ASDSP-II-2017-05-09-PD.pdf

Mworia, J.K. and Kinyamario, J.I. 2008. Traditional Strategies used by Pastoralists to cope with La Nina Induced Drought in Kajiado, Kenya. African Journal of Environmental Science and Technology, 2(1): 010-014.

Munyasi, J.W.; Gitunu, A.M.M.; Mayeki, J.K.; Muthiani, E.N. and Nyamwaro, S.O. 2012. Non-traditional land-use practices in the pastoral Maasai region in Loitokitok District of Kajiado County, Kenya. Journal of Agricultural Extension and Rural Development 4(16): 428-434.

Mutangah, J.G. 2015. Indigenous Knowledge: The Key to Biodiversity Conservation. Cultural Survival. http://www.culturalsurvival.org/publications/cultural-survival-quarterely/indigenous-knowledge-key-biodiversity-conservation accessed on 10.11.2017

Mutu, P.L. 2017. Causes of drought vulnerability and indigenous drought early warning methods among the Turkana nomadic pastoralists of Ilemi Triangle region of northern Kenya. Research in Health Science 2(2): 209.

Nahlik, A.M.; Kentula, M.; Fennessy, M. S. and Landers, D. 2012. Where is consensus? a proposed foundation for moving ecosystem services concepts into practice. Journal of Ecological Economics 77: 27-35.

Ng'ang'a, S.K.; Van Wijk, M.T. and Rufino, M.C. 2016. Adaptation of agriculture to climate change in semi-arid Borena, Ethiopia. Regional Environmental Change, 16 (8): 2317-2330.

Nori, M. and Davies, J. 2007. Change of Wind or Wind of Change? Climate Change, Adaptation and Pastoralism. WISP working paper prepared by IUCN, Nairobi. Accessed on 17.12.2018 from www.iucn.org/WISP/documents_english/wsp-CCAP-final-en.pdf

Nyong, A.; Adesina, F. and Osman E.B. 2007. The value of indigenous knowledge in climate change mitigation and adaptation strategies in Africa, Sahel. Mitigation and Adaptation Strategies for Global Change 12(5): 787-797.

OleSaitabau, H. 2014. Impacts of Climate Change on the Livelihoods of Loita Maasai Pastoral Community and the Related Indigenous Knowledge on Adaptation and Mitigation. National Museums of Kenya. Nairobi, Kenya. Accessed on 11.11.2017 from http://www.ethnobiology.net/wp-content/uploads/From-the-Field_Henry_ISE-Paper-2014.pdf.

Reynolds, J.F.; Smith, D.M.; Lambin, E.F.; Turner, B.L.; Mortimore, M.; Batterbury, S.P.; Downing, T.E.; Dowlatabadi, H.; Fernández, R.J.; Herrick, J.E.; Huber-Sannwald, E.; Jiang, H.; Leemans, R.; Lynam, T.; Maestre, F.T.; Ayarza, M. and Walker, B. 2007. Global Desertification: Building a science for dryland development. Science 316(5826): 847-51.

Ritho, C.; Mbogoh, S.G.G.; Ng'ang'a, S, Muiruri, E.J.; Nyangweso, P. M.; Kipsat, M.JJ.; Ogada, J.O.; Omboto, P.; Kefa, C.; Kubowon, P.C. 2012. Assessment of Farmers' Adaptation to the Effects of Climate Change in Kenya: Case of Kyuso District. Journal of Economics and Sustainable Development 3:52-60.

Schwartz, H.J.; Fratkin, E. and Roth, E.A. 2005. Ecological and economic consequences of reduced mobility in pastoral livestock production systems pages 69-84, In: Fratkin, E. and Roth, E.A (Editors), As Pastoralist Settle - Social, Health and Economic Consequences of Pastoral Sedentarisation in Marsabit District, Kenya Kluwer Academic Publishers, New York.

Tiwari, K. and Saxena, A. 2011. Change detection of land use/ land cover pattern in and around Mandideep and Obedullanganj. International Journal of Technology and Engineering Systems 2(3): 342-350.

Waila, J.M.; Mahero. M.W. and Namusisi, S. 2018. Outcome of Climate Change in a Marginalized Population: Ethnography of the Turkana Pastoralists in Kenya. American Journal of Public Health 108(2): 70-71.

Walker, B.; Holling, C.S.; Carpenter, S.R. and Kinzig, A. 2004. Resilience, adaptability and transformability in social-ecological systems. Ecology and Society 9(2):5-9.

Wasonga, V.O. 2009. Linkages between Land-Use, Land Degradation and Poverty in Semi-Arid Pastorals of Kenya: The Case of Baringo District. PhD Thesis, Department of Agriculture, University of Nairobi. Accessed on 11.4.2019 from http://erepository.uonbi.ac.ke/handle/11295/6426.)

Watson, E.E.; Kochore, H.H. and Dabasso, B.H. 2016 Camels and climate resilience: adaptation in northern Kenya. Human Ecology 44:701-713.

Received: 6 June 2020
Accepted: 25 July 2020