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

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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 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 and Geographic Information System were utilized based on Food and Agriculture Organization Land Cover Classification System where changes in the sizes of various land use patterns were; bare area, built-up area, cropland, forested land, grassland, riverine, shrubland, waterbody and wetland. The evaluation of these biophysical attributes showed gains in the bare area, built up area, cropland, forestland, grassland and loses in the riverine, wetland and waterbody. Land use transformation with the declining levels of natural resources is a threat to pastoralism and there is need for an all-inclusive land-use policies which will inform adaptation and resilience planning in Kajiado County, Kenya.

Keywords: Natural resources; pastoralism; biophysical attributes, land use and 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 occupies 80 per cent of the landmass and it is home to about 20-25 per cent of the country's population (ILRI 2006), who derive their ecosystem services from the region (Homewood et al. 2012). Kajiado County is one of the 27 ASAL counties in Kenya (MOALF 2017) where pastoralists rely on natural systems for their provisions and production needs (Watson et al. 2016; Carley et al. 2013). These people 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). Therefore, any form of disruption of natural systems in the ASALs, whether temporal or spatial, leaves the pastoralists with multiple production risks (Folk et al. 2010) which is manifested through the loss of livestock (Walker et al. 2004) and the Masa community is no exception for they have encountered loses of their herds (Roth et al. 2012; Ng'ang'a 2016). The dwindling natural resources in the ASALs prompted the evaluation of the land-use transformation of the area through mapping of natural resources.

METERIALS AND METHODS

Study area

Kajiado County is located in the southern region of Kenya bordering five counties, namely: Nairobi,

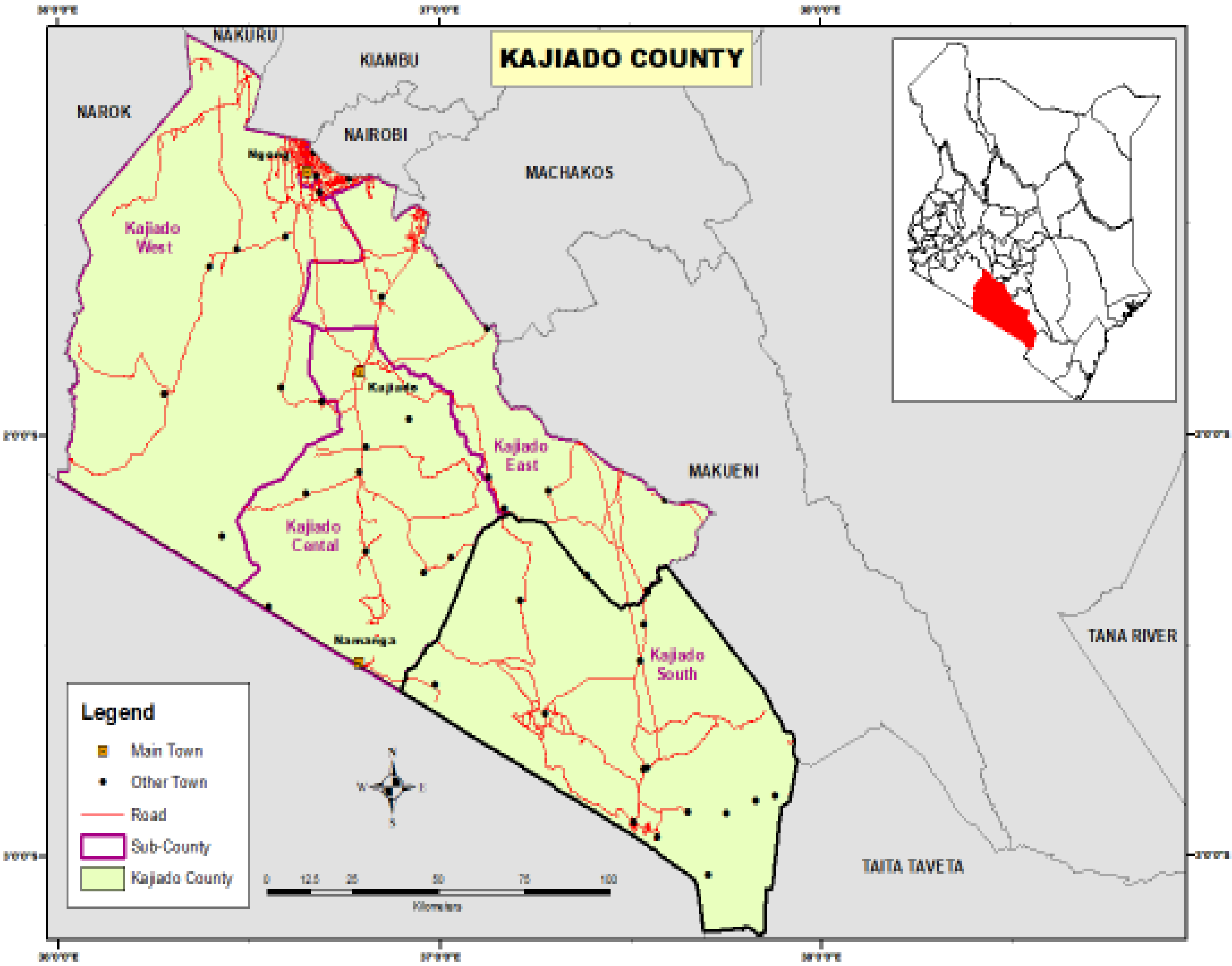

Figure 1. Study area

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° 02' and 3° 02' S and longitude 36° 52' and 37° 52' 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

Landsat dataset used to develop land cover maps for the years 1987, 2000 and 2015. These datasets were sourced from www.glovis.usgs.org and it is available as open data portal. The land use land cover mapping enabled the study to evaluate the status of biophysical attributes in the County, especially monitoring changes in natural resources.

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 Campbell (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. Thereafter, the GIS database generated is then run on an ArcGIS software to detect noticeable change. The GIS is a software used widely and its applications are constantly expanding over time.

The mapping development process was as follows:

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 focusing on the dry season imagery (cloud-free) i.e. January-March; 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. The classified data produced were edited using both interactive and batch mode. This process encompassed layer stacking, subsetting and mosaicking using Arc GIS and impact tool (JRC). The generated pre-processed database from which analysis was done utilised ancillary data in which case ILRI polygons 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 (Ederle *et al.* 2005) methodology in ENVI software platform from which each of period image with nine land use classes identified based on the Food and Agriculture Organisation (FAO) Land Cover Classification System (LCCS) was adopted hence 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 were done before the final interpretations. The first draft of images generated were further analysed. It involved field checks which further confirmed the identified land cover categories latent to the Landsat imagery. This was carried out according to Lillesand and Kiefer (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.

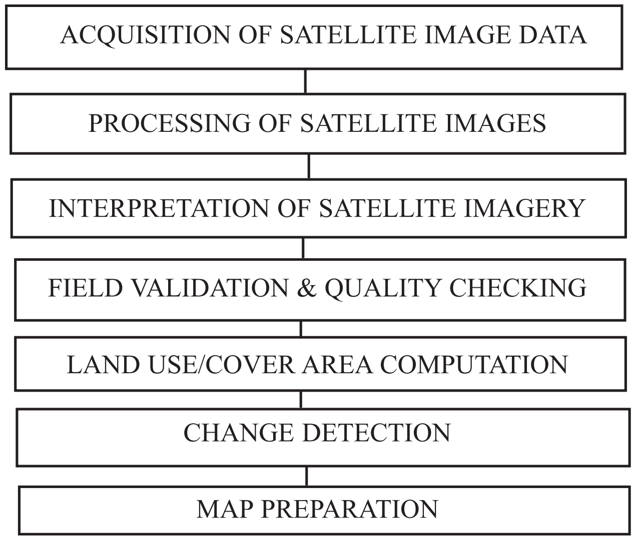

Figure 2. Study method

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.

The resulting maps which included 1987, 2000 and 2015 were imported and overlaid into ArcGIS software for analysis while factoring in the mainland 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.

Once the satellite data for each year had been obtained, GIS and Remote sensing method were applied to develop land cover maps for the years 1987, 2000 and 2015. These maps were subjected to validation using sample points collected from high-resolution images from Google Earth as ground truth data. Interpretations of changes in Land Use Land Cover in the form of statistics were derived from the land cover maps by cross-referencing the different years of the land covers, namely: between 1987 and 2000, 2000 and 2015 and 1987 and 2015.

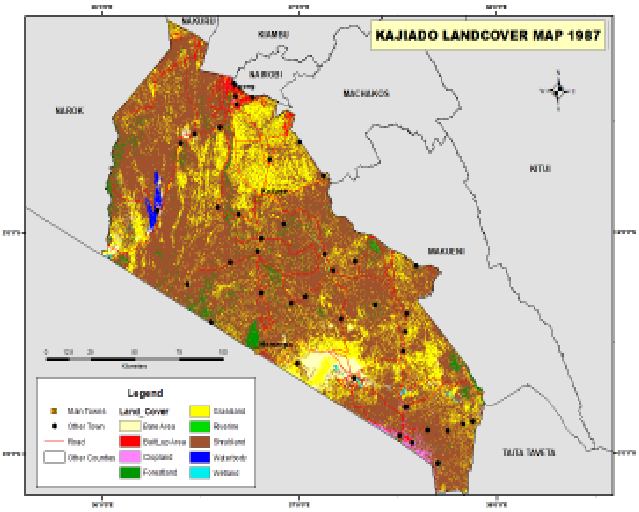

Figure 3. Land use map of 1987

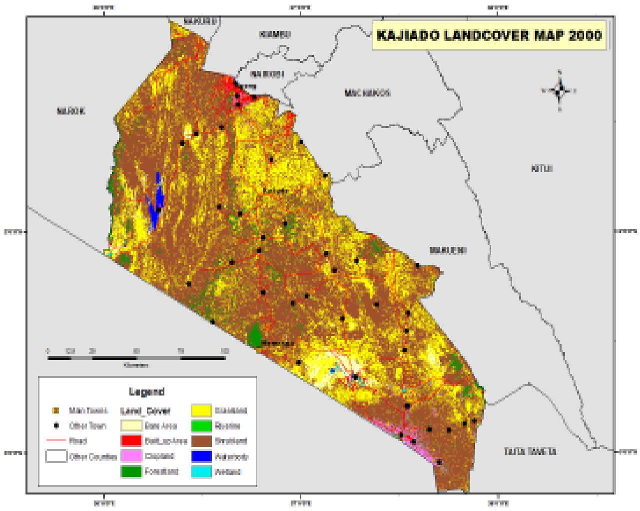

Figure 4. Land use map of 2000

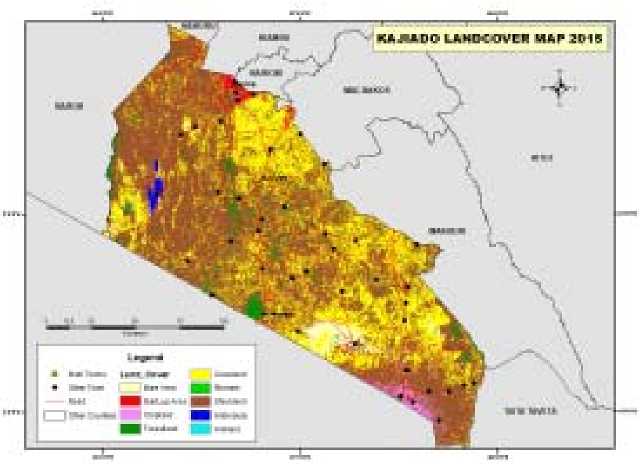

Figure 4. Land use map of 2015

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

$$R = \frac{Y-X}{T}$$

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 as shown in Figures 3, 4 and 5. These results on maps were subjected to validation using simple points collected from high-resolution images from Google Earth as ground truth data. Finally, these visualised maps were generated as the output based on the Food and Agriculture Organization Land Cover Classification System (FAO LCCS). These Land Use Land Cover maps captured the nine LULC types across the entire Kajiado County.

Statistics for land use land cover in Kajiado county

Statistics were generated based on the three maps as shown in Figures 3, 4 and 5 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 in Table 1 shows the summarized statistics for Land Use Land Cover Mapping.

Table 1. Statistic for Land Use Land Cover types in 1987, 2000, 2015

LULC types	Area (Ha)		
	1987	2000	2015
Bare area	55,130.31	48,676.95	56,517.48
Built up area	326.88	672.66	942.12
Cropland	15,382.80	23,997.24	30,295.89
Forestland	55,371.96	59,386.56	65,242.08
Grassland	480,015.81	609,967.98	691,588.80
Riverine	9,292.50	6,578.19	8,370.18
Shrubland	1,560,841.20	1,426,699.78	1,324,916.37
Waterbody	9,862.20	11,169.99	9,646.47
Wetland	3,848.94	2,987.10	2,544.84

Table 2 shows 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 with gains 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). Table 3 shows 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 with gains in a built-up area (346), cropland (8,614), grassland (129,952), forestland (4,015) and waterbody (1,307) and loses were in bare area (-6,453), riverine (-2,715), shrub land (-134,141) and wetland (-862).

Table 2. Land Use Land Cover changes from 1987 to 2015

LULC types	**Area (Ha)**		
	1987	**2015**	**Change**
Bare area	55,130	56,518	1,387
Built up	327	942	615
Cropland	15,383	30,296	14,914
Forestland	55,372	65,242	9,870
Grassland	480,016	691,589	211,573
Riverine	9,293	8,370	-922
Shrubland	1,560,841	1,324,916	-235,925
Waterbody	9,862	9,647	-216
Wetland	3,849	2,545	-1,304

Table 3. Land Use Land Cover changes from 1987 to 2000

LULC types	**Area (Ha)**		
	1987	**2000**	**Change**
Bare area	55,130	48,677	-6,453
Built up area	327	673	346
Cropland	15,383	23,997	8,614
Forestland	55,372	59,387	4,015
Grassland	480,016	609,968	129,952
Riverine	9,293	6,578	-2,715
Shrubland	1,560,841	1,426,700	-134,141
Waterbody	9,862	11,170	1,308
Wetland	3,849	2,987	-862

Table 4 shows results using 2000 as the initial year and 2015 as the final year, the actual changes under various LULC computed in hectares with gains in the 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 shrubland (-101,784) waterbody (-1,523) and wetland (-442).

Table 4. Land Use Land Cover changes from 2000 to 2015

LULC types	Area (Ha)		
	2000	**2015**	**Change**
Bare area	48,677	56,518	7,841
Built up area	673	942	269
Cropland	23,997	30,296	6,299
Forestland	59,387	65,242	5,855
Grassland	609,968	691,589	81,621
Riverine	6,578	8,370	1,792
Shrubland	1,426,700	1,324,916	-101,784
Waterbody	11,170	9,647	-1,523
Wetland	2,987	2,545	-442

Table 5. Land Use Land Cover change comparison in hectares between the early (1987-2000) and later (2000-2015) Period

LULC Types	**Change of Area (Ha)**	
	1987-2000	**2000-2015**
Bare area	6,453	7,841
Built up area	346	269
Cropland	8,614	6,299
Forestland	4,015	5,855
Grassland	129,952	81,621
Riverine	2,714	1,792
Shrubland	134,141	101,784
Waterbody	1,308	1,523
Wetland	1,524	442

Table 5 shows 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. 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 year

Table 6 shows 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 6. Rate of change

LULC Types	**Rate of change**		
	1987-2000	**2000-2015**	**1987-2015**
Bare area	-0.90	1.07	0.09
Built up	0.08	2.67	6.72
Cropland	0.04	1.75	3.46
Forestland	0.01	0.66	0.64
Grassland	0.02	0.89	1.57
Riverine	0.02	1.82	-0.35
Shrubland	0.06	-0.48	-0.54
Water body	0.01	-0.91	-0.08
Wetland	0.02	-0.99	-1.21

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. The heterogeneous nature of this landscape makes it suitable for pasture which is a requirement for a viable livestock production system. This observation is similar to that of Niamey and Fuller (2000) who reported that the area has vast biodiversity. Gunderson and Holing (2002) and Homewood et al. (2012) reported that the area is endowed with vast species (both fauna and flora) intertwined with unique landscapes and sites for tourist attraction. Additionally, they reported that the co-existence of wild and domestic herbivores in the non-protected area is attributed to palatable grass species associated with nomadic pastoralism. Similarly, Homewood and Rodgers (1991) and Mutagen (2015) reported that wild herbivores were exhibiting a high degree of spatial overlaps with livestock. Therefore, it is important to note that the unique natural assets, vast biodiversity and assemblage of wild herbivores attracts revenue, albeit indirectly, as tourism ventures extend goodwill by helping in the conservation efforts of the Masa pastoralists and it also complements the income of the pastoralists (Burn silver et al. 2003). Indigenous knowledge has thrived over time and it has been fostered by the relationships and complex exchange of knowledge among the Masa pastoralists (Ngong et al. 2007). Indigenous knowledge has helped them to be resilient and it has also enabled them to sustain their ecology (OleSaitabau 2014).

The results of Land Use Land Cover mapping indicated that the forestland had increased progressively. As stated earlier, the Maasai community has a strong conservation values especially when it comes to the conservation of 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) which also prompted the need for an in-depth understanding of their bio-cultural practices which in this context denotes a community's long-established rights, in accordance with its customary laws, to steward its land, water and natural resources, i.e. "a collective right to carry out traditional stewardship *vis-à-vis* nature" (Bavikatte and Bennett 2015). This stewardship structure is largely under communal land ownership which supports livestock production system. 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.

Land fragmentation is thriving on the basis to the weak land tenure systems with significant conversion to private landholdings raising concerns over pasture and water scarcity. Therefore, alternative field activities if left uncontrolled could adversely affect pastoralism in an area which is already faced with shrinking grazing space. Similarly, Carley et al. (2013) noted that significant areas of the habitat has been converted for alternative land uses which is a threat to pastoralism. Schwartz (2005) also reported that the increase in alternative land uses in the County has aggravated environmental degradation. Birch and Grahn (2007) reported that alternative land uses have created discord, promoted exclusivity and as such, increased production risks on pastoral livelihood system. The emerging scenario and the growth of private land ownership is a disjuncture from nomadic pastoralism that is traditionally associated with this region. As such, the Maasai pastoralists have ended up with multiple production risks. Moreover, their efforts to mitigate the water and pasture deficits have been frustrated since the vast open space where their livestock used to graze freely under communal trust has been rendered unattainable. The altered land use pattern has increased the Maasai's vulnerability for it has curtained their mobility (Cuni-Sanchez et al. 2016). Unfortunately, the change in land use is largely a policy issue thus out of their control (Ng'ang'a 2016). Additionally, Chibinga (2010) and Waila et al. (2018) reported that there was a policy direction that focused more on sedentary crop production which has had an adverse impact on pastoralism. Furthermore, the Maasai Pastoralists have been left out in development debates and they are not involved in the planning and decision-making processes when it comes to issues touching on their environment and economic livelihood (Mutu 2017).

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 for resettlement close to water resources increasing water demand for water in an area that is already faced with water scarcity. Similarly, (Juma 2009, Watson et al. 2016) reported that despite the County's by receding surface water, there is increased water demands attributed to changes in land use patterns which is detrimental to the pastoralism. Furthermore, ecological conversion with considerable degradation could negatively affect livestock production. Similarly, Wasonga (2009) and Munyasi et al. (2012) reported degradation and low natural vegetation cover in some parts of Kajiado County. Kidake et al. (2016) reported the extended bare areas and proliferation by invasive species with adverse effects such as low milk and meat production (Mapiye et al. 2006). 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 since they are known to suppress the indigenous and palatable grass species and their segregation from the rest of the pasture is almost impossible. This observation is similar to that of Kidake et al. (2016) who reported that there is a significant spread of invasive species of up to 60-80 per cent in the grass pasture fields in Kajiado County yet the sustainability component of pastoralism is pegged on the availability of natural resources. In this context, the degraded landscapes and the indeterminate status of invasive species could make the food insecurity situation in the area even worse considering that the Maasai pastoralists have limited adaptation options at their disposal. Similarly, Bobadoye et al. (2016) noted that the limited access to critical resources by the Maasai pastoralists pose a threat to their sustainability. Therefore, at such times of scarcity, stewardship structures are adversely affected and they 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 Kramer and Brewer's (1984) economic theory which states that "where there is high competition for resources, social non-conformity dominates". Therefore, the shrinking natural resource base and the loss of significant portion of grazing space with the spreading invansive species in the area poses a threat to sustainability of pastoral livelihood system.

CONCLUSIONS

The study noted that the deliberate actions taken by the Maasai community to safeguard their habitat were bearing fruits. However, they have been misunderstood by outsiders who argue from the point of unknown. The outsiders view pastoral livelihood as backward and environmentally destructive yet the Maasai community have somehow managed to maintain their unique habitat by making use of their exceptional biophysical attributes such as vast biodiversity and assemblage of wild herbivores. Nevertheless, the push for sedentary agrarian-driven system is so strong despite it lacking the sustainability component which can compromise their pastoral Social-Ecological System. Alternative land uses which are incompatible to the pastoral livelihood system have worsened competition and rivalry as most of the natural resources have shrunk and left the community vulnerable. It is against this backdrop that cultural practices have been recognized as prudent pathway for sustainable pastoralism.

The weak land tenure system, characterized by haphazard land allocation with obscure demarcation that does not consider pastoralists' mobility needs and it is a threat to pastoralism. Therefore, there is a need for community involvement in land adjudication especially on transboundary resources to minimise rivalry in land use.

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Conflict of Interest: Authors declare no conflict.

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