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Analysis of land use and land cover change in Rusinga Island, Kenya

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Sustainable land restoration requires a powerful and adaptable system that is able to capture local community views in decision making process. Participatory GIS was employed in analyzing LULCC in Rusinga Island. Data were collected in Rusinga West and Rusinga East location. Resource mapping exercise was undertaken during FGDs consisting of 12 members per location with good knowledge of LULCC. The participant represented graphically the perceived changes that occurred in 1978, 1998 and 2019. Common LULCs identified were forestland, croplands, settlement, grazing and bare areas. Photograph of the mental maps was taken using digital camera and digitized in Arc Map 10.7.1. Features recorded on the maps were taken using a GPS and used for geo-referencing and assisted in the analysis. Results showed significant changes (P<0.05) under settlement and forest in Rusinga West while significant changes occurred in forest, bare areas and settlement in Rusinga East between the years 1978 and 2019. This study revealed the importance of local community knowledge of both spatial and temporal changes occurring within their territories. Participatory GIS can be adopted by the county government in involving the local community because it is a valuable approach.

Key words: Land use and land cover change, PGIS, Rusinga Island.

INTRODUCTION

Land use and land cover change (LULCC) have attracted global attention due to sustainability issues and need for research (Altaweel et al., 2010; Turner et al., 2007; IPCC, 2012). They alter the health of vegetation, hydrologic flow, decrease availability of products and services, reduce farm production (Lambin et al., 2003; Bai et al., 2008; Bajocco et al., 2012). The main divers of widespread LULCC include population increase, policies and governance, poverty, climate change, and agricultural intensification (Lambin et al., 2001; Brassoulis, 2000; Leemans and Groot, 2003; Gamble et al., 2003; Geist et al., 2006). Understanding LULCC is important and information generated is used in mitigating these impacts and planning for sustainable land use.

LULCC is also recognized in Kenya as the most pervasive driver of land degradation and can have long term implication for environmental and ecosystem functioning (Waswa, 2012). For instance, according to Bai et al. (2008), 64% of land in Kenya was moderately degraded while 23% was severely degraded in the year 1997. Le et al. (2014) showed that about 22% of land has degraded between 1982 and 2006 and this includes 30%

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of cropland, 46% of forest land, 42% of shrub lands and 18% of grasslands. Further, land degradation assessment conducted in Kenya in 2016 show that land degradation is likely to occur on about 61.4% of the total area in Kenya and this includes regions such as Lake Victoria basin (Ministry of Environment and Natural Resources, 2016). Among the common forms of land degradation include grassland and forest degradation (de Graff, 1993; Ministry of Environment and Natural Resources, 2016).

Understanding the complexity of LULCC requires the use of multiple methods for study (Campbell et al., 2005). Local community knowledge is arguably the most important way to understanding their interaction with environment (Rambaldi et al., 2006). Remote sensing (RS) and Geographic Information System (GIS) have been widely applied in resource management over the years but have failed to recognize the knowledge that people have and have shared from generation to generation (Perez, 2003: Rambaldi et al., 2006). Emerging issues of LULCC have prompted the need to adopt methodologies that ensure local community participation in the decision-making process. This has birthed Participatory Geographic Information System (PGIS) (CTA, 2016).

Participatory GIS is a practice in which local communities share their knowledge and opinions to help generate maps to inform management and assist in decision-making (Rambaldi and Weiner, 2004; Carver et al., 2001; CTA, 2016). Local knowledge is very important in natural resources management (Chambers et al., 1991 and Perez, 2003). This practice aims to address sustainable land management because people are involved in the planning process and ideas of underrepresented community are taken into consideration (Rambaldi et al., 2006; Di Gessa, 2008). Participatory GIS also offers the advantage of communication and eliminates the drawbacks of top-down impositions and favor technologies that attempt to understand the social and ecological foundations of traditional knowledge systems (McCall and Minang, 2005; Corbett, 2009). Local communities are able to appreciate the spatial implications of policies and actions while the policy makers realize the legitimacy of local interests. Participatory GIS also tends to involve more stakeholders during planning process. Moreover, PGIS empowers, develops skills in graphically presenting ideas, problems, to better analyze, communicate ideas and to implement more sustainable projects. According to Zurayk (2003), PGIS is a tool that is useful, practical and cost effective.

Studies have employed PGIS and have been successful in enhancing the participation of local community. Malaki et al. (2016) used PGIS to asses LULCC in Nguruma sub catchment in Kajiado. Participatory maps revealed significant changes in croplands, bare land, settlement and wetland. The local community was able to recommend measure that could bring positive changes to the environment such as involving the community in resource management. Anyekulu et al. (2006) used PGIS to monitor and evaluate LULCC in Begesheka, Tigray, Ethiopia. The main objective was to facilitate the assessment of land use changes over the past 50 years in Tigray, Ethiopia, through the representation and evaluation of social and ecological drivers of that change as perceived by the traditional knowledge systems. Results showed that highest conversion was forest to arable land (75%) followed by grazing to arable land (11%). PGIS helped to convince land management officials that local knowledge was truly representation of the experiences of the community.

Johansson and Isgren (2017) used PGIS to assess local perception of land use change in Kiloimbero, Tanzania. The results showed that PGIS can assist to understand and communicate complex interaction between socio-environmental effects and drivers of LULCC. Mapedza et al. (2003), used PGIS to investigate processes governing land cover change in Mafungambusi forest in Zimbabwe from the year 1976-1996. The study found that forest cover remained stable but it had shown steady decline during this period. The community pointed out planting of trees as a sustainable way to manage the forest.

Sakimba (2016) employed PGIS to understand community perception on spatio-temporal changes in pastoral resources in Amboseli ecosystem. The study results showed significant changes in grazing area, livestock routes, increase in settlements and trading centres. The study showed that participatory resource mapping was a key tool for engaging local community in mapping resources and planning for resource management. Kathumo et al. (2012) used PGIS to understand complex LULCC in the Lower Tana River Forest Complex. The main objective of the exercise was to create awareness among local community on the effects of the present decline in forest cover and educate them on the need for conservation of forest resource. Significant changes were found in forest cover and area under agriculture between the years 1970-2011. Settlement area did not change significantly in the same period. Changes in forest cover were manly associated with illegal logging, charcoal burning and overgrazing. The community also noted benefits as a result of LULCC such as increase crop production. Through PGIS the community was convinced of the importance of conserving the forest through practices such as afforestation.

Baaru and Gachene (2016) used PGIS to analyze changes in natural resources in Kathekakai, settlement scheme in Machakos County. The objective was to discuss possible effects of LULCC. The study revealed that natural resources reduced since the scheme became settlement. Forest decreased and replaced with exotic trees. More land was cleared for cultivation, river dried and soil erosion advanced in the area. Participants also mentioned reduction in crop production, drought cases,

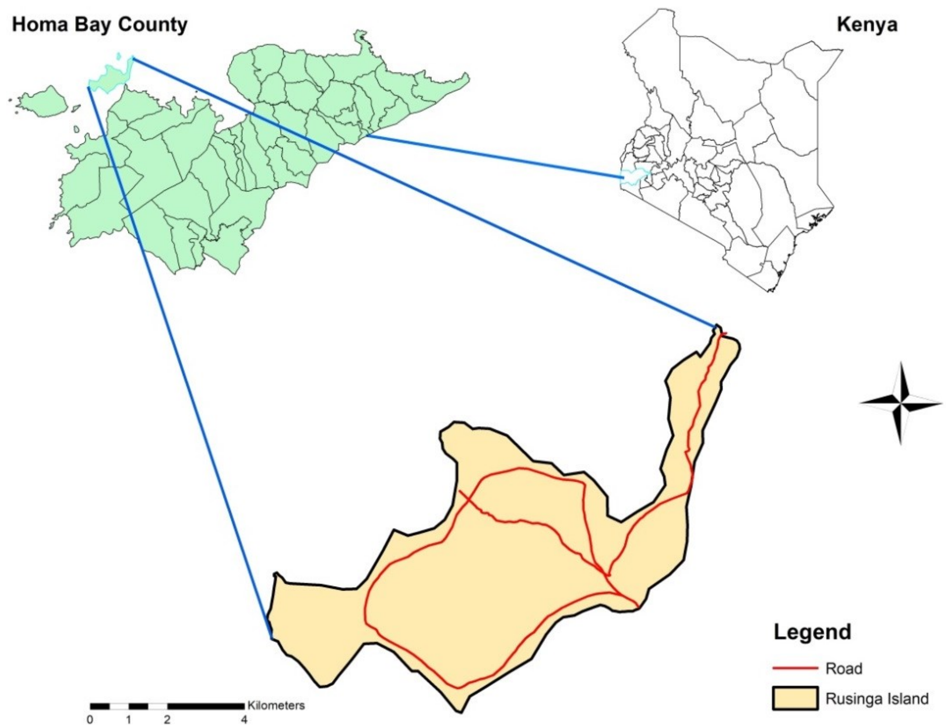

Figure 1. Map of the study area.

and higher daily temperature as indicators of climate change. Water harvesting techniques and adoption of tolerant crop were considered as adaptation strategies. Through PGIS, it was noted that resource management at the local community level is a challenge and more can be done to enhance sustainable land management. Syombua (2013)'s study on linking local community to LULCC and their implication to human wildlife conflict using PGIS, found out that agriculture shaped the nature and extend of human-wildlife conflicts. The results showed significant changes occurred in woodland, rainfed and irrigated areas while forest did not show significant changes. Through PGIS the community was convinced to participate in managemnet of human-wildlife conflicts. Rambaldi et al. (2006) and Rambaldi et al. (2006) used PGIS and included mapping results into planning and conservation of biodiversity. They further recommended PGIS to be applied on other areas to assist generate relevant information to assist in sustainable land use planning.

It is clear that local community can be involved using PGIS tool and information generated is necessary in enhancing sustainable land management. This can be useful in Rusinga Island which is at risk and accurate and timely information on LULCC is needed. Badilisha Ecovillage Trust has been working with the local community to enhance land management through bundled practices known as permaculture. There is no evidence of the study which has been done in this area using PGIS with documented results. The objective of this study was to determine LULCC using PGIS in Rusinga Island.

MATERIAL AND METHODS

Study area

Rusinga Island covers an area approximately 44 km^2 with an elevation between 1100 and 1300 meters above sea level and lies between latitude 0° 35'S and 0°44'S and longitude 34° 11'E and 34 ° 22'E. Administratively, Rusinga Island ward is part of Homa Bay County. The study area receives mean annual rainfall of 535mm which is greatly influenced by the relief with mean minimum and maximum annual temperature of 16°C to 34.8 °C (Suba DDP, 2008; Sombroek et al., 1982; Connelly, 1994; Jaetzold et al., 2005).

Rusinga Island has a diverse land landscape typified with hills and sloping areas. The major soils are ferrasols (Jaetzold et al., 2005) whose fertility is characterised as moderate to low. Agriculture is the major occupation with maize, beans, millet, sorgum, cassava being the major crops produced. Fishing especially near the shores of Lake Victoria is done by the surrounding community but due to over exploitation and reduction in fish people have embarked on farming activities (Suba DDP, 2008). The major agricultural challenge is drought, unpredictable rainfall pattern and land degradation (Connelly, 1994; Suba DDP, 2008). Apart from cropland, other land cover types include forest cover and settlement. The common tree species include *Senna simmea* and *Acacia seyal*. Rusinga Island is mainly inhabited by luo community. The current population is 29,412 with a population density of 685 persons per square kilometer (KNBS, 2019) (Figure 1).

Data collection

Participatory resource maps were drawn for Rusinga West and Rusinga East location. Maps were drawn for 1978, 1998 and 2019. Twelve participants who had good knowledge of the environmental change in the area were purposely selected from each location based on age, gender and level of education. Four men and women aged 60 years and above and who had stayed in area all there life and were aware of how the environment has changed overtime and 2 young men and women less than 40 years who had attained primary education and above were invited to participate in the exercise. Participatory GIS are the best method to collect information using FGDs (Mulwa and Ndung'u, 2003) and most studies on socioeconomic dynamics as well as natural resources management employ FGDs (Odimegwu, 2000).

The objective of the PGIS exercise was discussed and roles assigned to the participants. The participants were taken through the tools to be used for the PGIS exercise. This consisted of Manila papers (75cm by 50cm) for graphic presentation of spatial information, felt pens, and Geographic Positioning System (GPS). Symbols representing different LULC types were also agreed upon. Mapping involved graphically representing LULC types for the period 1978, 1998 and 2019 based on local community knowledge of LULC. This period was considered enough for the participant to detect changes. The common LULC indicated were forest, settlement, croplands, grazing land and bare areas. After drawing exercise, field survey with local key informants was done to validate points of interest/ reference points with GPS. Five GPS points were taken for each LULC category for geo-referencing the maps which were introduced in GPS and areas were converted to shape files.

Data on drivers of LULCC and sustainable land use management strategies were collected in Rusinga West and Rusinga East location using semi-structured questionnaire from 196 household. Households to be interviewed were randomly selected from the sampling frame developed through generating of random numbers assigned after homestead mapping with the help of the local Sub-Chiefs and village elders of the administrative areas from the households of each sub-location. The household was the sampling unit whereby the natives were interviewed. From each household, husband and wife were interviewed. Key questions included perceived drivers of LULCC and solution of LULCC. Five trained enumerators were used to carry the survey in the two locations under close supervision by the researcher. Besides, discussions were carried out with key informants including experienced farmers, agricultural officer from the County ministry of Agriculture, administrators and representative from Badilisha Ecovillage Trust, Rusinga Island Organic Farmer Association (RIOFA) and Rusinga Island Trust as well as field observation.

Data Analysis

Participatory resource maps were used to assess changes in LULC as perceived by the local community. Photographs of the maps were taken using a digital camera. The final mental maps were later geo-referenced and digitized using Arc Map 10.7 software and converted to shape files. The area under each LULC category including extent and magnitude of change was calculated from the original extent. The percentage areas covered by various LULC were calculated in excel. Chi-square goodness of fit was determined to test for the levels of significance of changes in LULC.

RESULTS AND DISCUSSIONS

Socio-demographic characteristics of the sample household

Table 1 shows the key demographic and socioeconomic characteristics of the surveyed households. Fifty four percent of the interviewed households were headed by female whereas male constituted the remaining 46%. Large proportion (33%) of the respondents were 56 years and above while 20% and 24% of them were between 46 and 55 years and 36 and 45 years respectively. Another 22% had 35 years and below. Forty four percent had attained basic primary education while 36% had attained secondary education. A small proportion of the household heads (7%) had no basic education and never went to school.

Rusinga Island family are large size family with majority (69%) having more than six members in the family. The farm size of the household in the study area are small size with majority (82%) owning three an acres and below.

Relatively, a larger proportion 53% of the respondents were engaged in farming activities and some of them 36% were engaged in small business like fish trading and selling of charcoal and wood. Another 11% were in formal employment. A large majority of the surveyed household (72%) in both Rusinga West and Rusinga East were involved in tree planting activities in their homestead and nearby farms.

Changes in Land Use and Land Cover

Participatory GIS provided a platform for the local community to express their spatial knowledge of LULCC over the past forty years as shown in Tables 2 and 3, respectively. Similar trend in LULC were shown in both study areas. The main LULC were forest, cropland, settlement, grazing and bare areas which the area coverage varied over the period of study. In Rusinga East, the study results showed that the area under forest dropped steadily by 53% in the three time periods. The area under settlement increased by 11% between 1978 and 1998 and increased by 13% between 1998 and 2019. There was an overall increase of 24% in the area under settlement between 1978 and 2019. The area under cropland increased by 4% between 1978 and 1998 and increased by 7% between 1998 and 2019. There was an overall increase in area under cropland by 10% in the three time periods. Grazing and bare areas increased in the three time periods with an overall increase of 9 and 10% respectively. The finding generally showed that the forest area decreased while the area under cropland and settlement increased steadily over the period studied. Similarly, bare areas also increased. This was may be due to clearing of forest for creation of cropland and cutting of trees for building materials and burning of charcoal to sustain livelihoods which leaves most parts bare in Rusinga West.

Similar LULC types were described in Rusinga West location. The area coverage under each LULC was shown to have changed in the three-time period. Forest decreased by 29% between 1978 and 1998 and further decreased by 18% between 1998 and 2019. Settlement

Table 1. Households' demographics.

Socioeconomic characteristics	Rusinga Island					
	Rusinga East		Rusinga West		Total	
	%	N 98	%	N98	N196	%
Gender						
Female	59.2	58	55.1	54	106	54.1
Male	40.8	40	44.9	44	90	45.9
Age						
<35	18.3	18	25.5	25	43	21.9
36-45	24.4	24	24.4	24	48	24.5
46-55	29.5	29	10.2	10	39	20.4
≥56	27.8	27	39.9	39	66	33.2
Education						
Never went	4.1	4	11.2	11	14	7.7
Primary	40.8	40	47.9	47	87	44.4
Secondary	40.8	40	30.7	30	72	35.7
College	12.3	14	10.2	10	23	12.2
Family size						
<5	40.8	40	57.1	56	61	31.1
≥6	59.2	58	42.9	42	135	68.9
Farm size						
<3	79.6	78	89.8	88	161	82.2
≥4	20.4	20	10.2	10	35	17.8
Occupation						
Farming	51	49	55.1	54	52.5	103
Business	41.8	41	30.1	30	36.2	71
Employed	8.2	8	14.8	14	11.3	22
Involved in tree planting						
Yes	67.4	66	76.5	75	71.9	141
No	32.6	32	23.5	23	28.1	55

Table 2. Extent and proportion of different LULCC for the period 1978-2018 in Rusinga East

LULC Category	Area (Km²)			Percentage change		Overall % change	Chi-square test		
	1978	1998	2018	1978-1998	1988-2018	1978-2018	χ2	df	P- value
Forest	14.05	6.64	1.78	-31.94	-20.95	-52.888	10.716	2	0.0035
Settlement	2.6	6.12	8.06	+15.2	+8.362	+23.53	11.466	2	0.0035
Cropland	4.08	4.98	6.48	+3.88	+6.466	+10.34	1.4118	2	0.5875
Grazing areas	1.97	3.96	4.08	+8.58	+0.517	+9.095	2.2599	2	0.5875
Bare ground	0.5	1.5	2.8	+4.31	+5.603	+9.914	10.58	2	0.005
Total	23.2	23.2	23.2						

area also increased in the same period by overall 24%. Area covered by cropland decrease and increased in the three study periods. The results showed that between the years 1978-1998, the area under cropland decreased by 3% and increased by 7% between the years 1988-2019. Grazing and bare areas increased throughout the three-study period. There was an overall increase in grazing and bare areas by 6 and 8% respectively.

Tables 2 and 3 show the Chi-square goodness of fit whether the changes in LULC were significant in both Rusinga West and Rusinga East location. Significant changes in land cover that occurred in forest ($\chi 2$= 10.716,

Table 3. Extent and proportion of different use and land cover change for the period 1978-2018 in Rusinga West.

LULC Category	Area (Km²)			Percentage change		Overall % change	Chi-square test		
	1978	1998	2018	1978-1998	1988-2018	1978-2018	χ2	df	P-value
Forest	10.05	4.45	0.86	-29.17	-18.7	47.865	8.4036	2	0.015
Settlement	4.8	9.31	12.24	+23.5	+15.26	+38.75	11.532	2	0.0035
Cropland	3.1	3.64	2.28	+2.81	-7.083	-4.2708	0.2169	2	0.5875
Grazing areas	0.8	1.3	1.91	+2.6	+3.177	-5.781	1.5401	2	0.5875
Bare ground	0.45	0.5	1.91	+0.26	+7.344	+7.604	4.7369	2	0.075
Total	19.2	19.2	19.2						

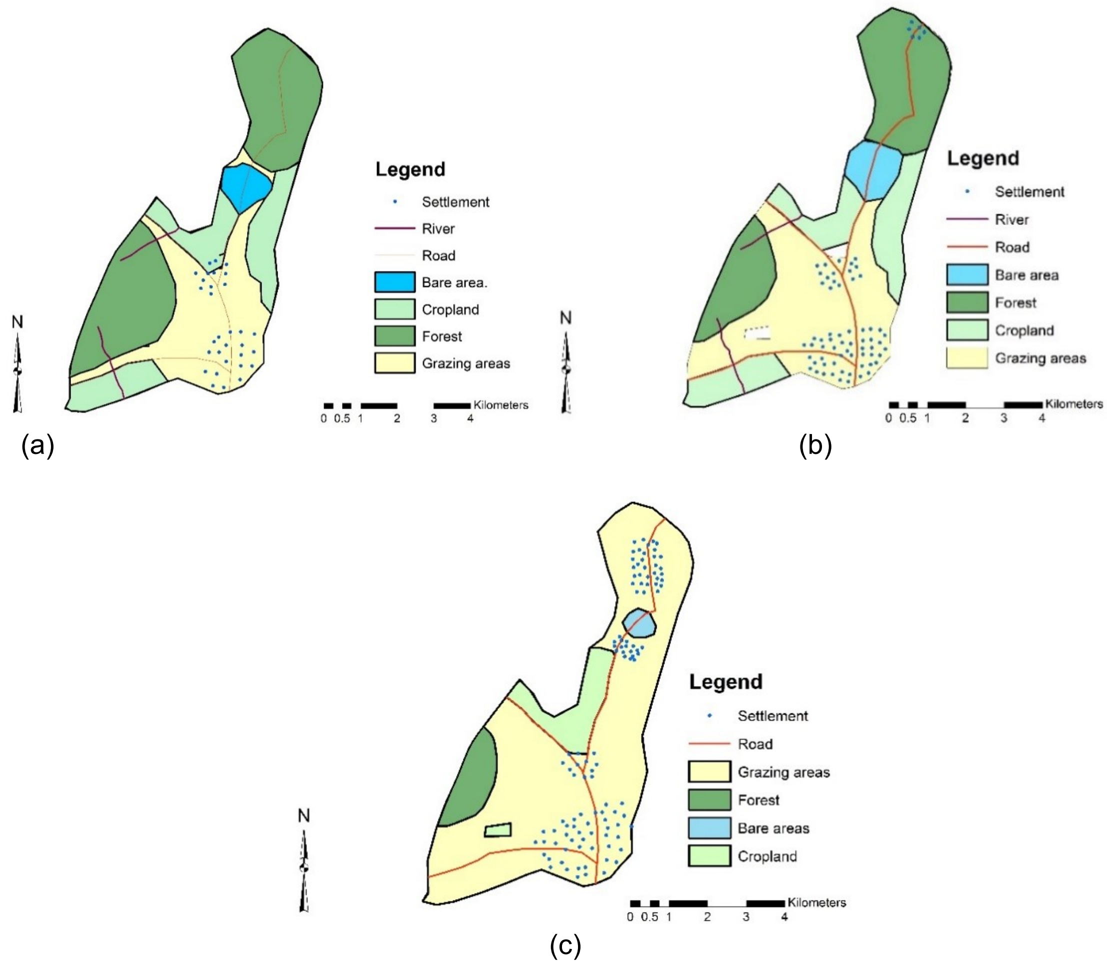

Figure 2. Rusinga East PGIS maps for the years 1978 (a), 1998 (b) and 2019 (c)

df= 2, P-value= 0.0035), bare areas (χ2= 10.58, df= 2, P-value= 0.005) and settlement (χ2= 11.466, df= 2, P-value= 0.0035) in Rusinga East location. Changes in cropland (χ2= 1.4118, df= 2, P-value= 0.5875) and grazing land (χ2= 2.2599, df= 2, P-value= 0.5875) were insignificant. Likewise, significant changes in LULC were observed in settlement (χ2= 11.532, df= 2, P-value= 0.0035) and forest (χ2= 8.4036, df= 2, P-value= 0.015) in Rusinga East. Cropland (χ2= 0.2169, df= 2, P-value= 0.5875), grazing (χ2= 1.5401, df= 2, P-value= 0.5875) and bare ground (χ2= 4.7369, df= 2, P-value= 0.075) showed insignificant changes. This may be due to changing livelihood options, as well as clearing of forest to create space for settling. Such activities may have tremendous effects in terms of altering the LULC (Figures 2 and 3).

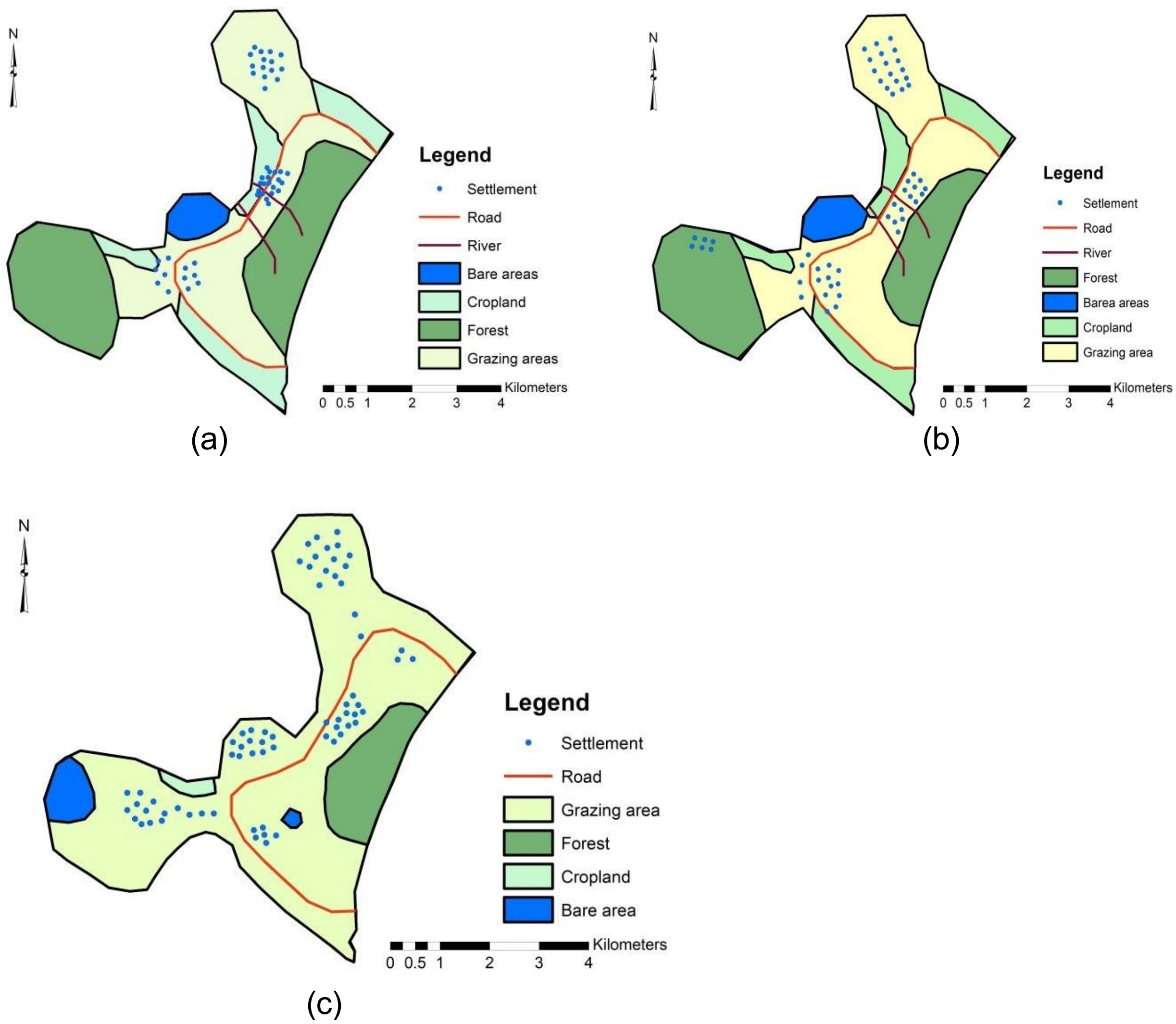

Figure 3. Showing Rusinga West PGIS maps for the years 1978 (a), 1998 (b) and 2019 (c).

Greatest LULCC occurred in forest (P= 0.015) and settlement (0.0035) in Rusinga West and Rusinga East. While, change in cropland was insignificant in both Rusinga West and Rusinga East location. Change in bare area was significant in Rusinga East location and showed insignificant change in Rusinga West. The reduction in forest and increase in settlement and bare areas may be an indication of harvesting of forest products such as timber and poles for building. Cutting of trees leaves land bare which is supported by increasing bare areas. Increase in population not only affects the land under forest but also cropland due to clearing for creation of farmland as reveled in this PGIS study. Studies in Kenya and East Africa employing PGIS report similar results. Kathumo et al. (2012)'s study using PGIS to assess LULCC in Lower Tana River Forest Complex, found out changes under agricultural land were insignificant in Baomo village between 1970 and 2011 and significant in Maisha Masha village in the same period. Syombua (2013) reported significant changes in irrigated agriculture and forest cover in Kitobo village Taita Taveta County from 1970-2012.

Malaki et al. (2016)'s study using partcipatory GIS analysis to understand LULCC in Nguruman sub-catchment, found that area under forest decreased by over 76% in Entasopia sub-location while in area under settlement and bare area increased by 521 and 1383.33% respectively between the year 1994 and 2004. Mapedza et al. (2003) noted that forest cover decreased from 68-66% from the year 1976 -1984 and rose again to 71% in 1996 in Mafungambusi, Tanzania. Anyekulu et al. (2006) using particpatory GIS found that most of the coversion occurred from forest to arable land by 75% in Begasheka Watershed, Ethiopia for over 50 years. Sakimba (2016) using particpatory GIS to understand LULCC, noted that area under settlement increased by

Table 4. Perceived drivers of LULCC.

Driver class	Types of Drivers of LULCC	Percent	
		Rusinga West	Rusinga East
Socio-economic	Population increase	12.5	8.4
	Forest clearance	10.6	10.8
	Clearing for settlements	10.7	11.4
	Excessive Charcoal and wood productions	12.2	11.5
	Tree felling for timber, poles and building	9.5	9.3
	Increase in number of animals	7.4	6.4
	Poverty	12.1	13.3
Environmental	Land degradation	7.7	9.1
	Drought and low rainfall	9.4	13.2
Governance	Policy issues and land tenure	7.9	6.3
Total		100	100

21% for the period 1967-2015 in Amboseli ecosystem Kenya. Abonyo et al. (2007)'s study on LULCC using pGIS in Ssese Island Uganda observed that grazing areas dropped from 26.62% in 1960 to 17.41% in 2006 while small scale agricultural area dropped from 3.36 to 1.50% in the same period.

Local Community Perception about Drivers of LULCC

Table 4 summarizes the drivers of LULCC as perceived by the local community in both Rusinga West and Rusinga East location. The drivers of LULCC fall into three categories mainly socioeconomic, environmental and governance. In Rusinga West, majority of the respondents believed that occurrence of LULCC was highly caused by socioeconomic drivers such as increased population (13%), clearing for settlement and farming activities (11%) and excessive charcoal production (12%) and high poverty (12%) levels among the local people. While this was the case in Rusinga West, majority in Rusinga East location believed that LULCC was mainly a combination of environmental factors mainly drought (13%) and socioeconomic factors including poverty (13%), charcoal burning (12%), and clearing for settlement (11%). A higher percent (8%) in Rusinga West than in Rusinga East (6%) believed that weak governance mainly policy and land tenure issues was also responsible for occurrence of LULCC.

Population increase is still the most important force of LULCC. It exerts pressure on land resources by increasing demand for goods such as timber, poles and charcoal and land for settlement (Amare, 2013). Most families in the study area are large size families and poor and rely on farming and forest products for their livelihoods. During FGDs, the local community stated that family size had continued to rise in the recent past in the region and every man is building a home. Participatory GIS analysis revealed significant changes in bare and forest areas in Rusinga East and Rusinga West reflecting the potential impact of these drivers. The findings of this study are similar to that of Abonyo et al. (2007); Gessesse and Bewket (2014); Baaru and Gachene (2016); Kathumo et al., (2012); Worku and Deribew (2018); Amare (2013); Kindu et al. (2015); Hosonuma et al. (2012) and Jalilova and Vacik (2012).

Clearing of forest for farming, settlement and excessive charcoal burning reflects the pressure exerted by population increase in the study area. A high number of farmers in both Rusinga West and Rusinga East believed that these drivers were key in causing LULCC. Community perception may be true according to the finding of Hosonuma et al. (2012); Kindu et al. (2015) and Laukkonen et al. (2009) who showed that population increase and clearing for farming may also accelerate environemental change through causing land degradation and resource depletion

During interviews with farmers they mentioned animal rearing. Animals such as cows, sheep, goats and donkeys were kept as a source of income and wealth. They stated that animals were also kept as a way of cushioning themeselves from the effects of failing crops and that the number of animals owned by every household had increased. However, they also believed that uncontrolled grazing system of grazing practiced by the local community needs to be managed sustainably. Even though they kept animals, they also complained lack of feeds which they asociated to frequent drought, unreliable rainfall and poor soils. This may be true due to climate change which has continued to exert many effects. These have made some families to shift to forest product for their livelihood. According to Campbell (1990), this is the real case of farmers living in rural areas and relying on different economic activities to sustain livelihood espacially in the area proned to land degradation, drought and climate variability and vulnerability across Sub Sahara Africa.

Majority in Rusinga East than in Rusinga West believed

Table 5. Perceived effects of LULCC.

Perceived effects of LULCC	Percent	
	Rusinga West	Rusinga East
Drying of water sources	15.5	12.2
Soil erosion and land degradation	20.4	19.3
Death of animals	9.7	15.2
Climate changes	15.1	12.3
Shortages of animal feeds	15.1	14.1
Deforestation	11.8	9.5
Reduced crop yield	12.4	17.4
Total	100	100

that land degradation and drought are key factors behind LULCC. According to Suba DDP (2008), land degradation and climate change are the main environmental factors affecting local community in the study area. Drought reduces the vegetation cover by affecting regeneration potential of a locality. Discussions and interviews with key infromants kept on referring to frequent drought cases in the region with some years going without rain. The more recent one occurred in the year 2007 which affected regeneration of the vegetation cover, people and animals (Odula, 2019).

Governance policy and land tenure ware also cited by farmers as drivers for LULCC; however they were not considered to have higher maginitude in both the study site. Weak governance of land can cause LULCC. Jalilova and Vacik (2012)'s study assesing local people perceptions of forest biodiversity in the Walnut fruit forest of Kyrgyzstan found that lack of government management was the main driver of biodiversity loss. The findings by Abonyo et al. (2007) showed that poor government policy of allevating poverty through agricultural modernization was responsible for massive LULCC in Ssese Island in Uganda.

Local People Perception on the Effects of LULCC

The local community associated LULCC with several undesirable effects in both Rusinga West and Rusinga East (Table 5). The main effects of LULCC included advancing soil erosions, reduced crop yields, drying of water sources, dying of animals, deforestation and climate change. There was no positive effect mentioned in both the study areas. This may be because the undesirable effects were more of concern to the local community. This may be true according to Trudgill (2014) who showed an increased concern over LULCC. Majority in Rusinga East than in Rusinga East however mentioned dying of animals and reduced crop yield as the effect of LULCC. These may be because, the respondents in Rusinga East reared animals. In both the study site, majority mentioned soil erosion as the effect of LULCC. Baaru and Gachane (2016), Negasi et al. (2018) and Kathumo et al. (2012) reported similar negative effects of LULCC in their studies.

Deforestation as perceived by the local community increases the rate of soil erosion by increasing the rate of surface runoff and reducing surface protection by vegetation cover. Deforestation also affects the hydrologic flow (MoA, 2009; Negasi et al., 2018). With PGIS the local community was able to mention rivers specifically Lisiwi and Nyamita which had dried.

Reduced crop yield was associated with declining soil fertility in farms which is aggrevated by soil erosion and recurring drought cases. They mentioned that most soils had low soil fertility and were shallow due to soil erosion. They mentioned that yields obatined from crops such as maize, sorghum and cassave were very low. The finding of this study collaborates with that of Toh et al. (2018) which showed that majority of the farmers recognize declining soil fertility as a constraint resulting from LULCC.

Climate change is a global issue and has been predicted to continue in Sub Sahara Africa with devastating effects. This may shift livelihood strategies such growing multipurpose crops to raise yield and keeping animals. With lack of proper land management, this may cause LULCC and associated land degradation (MoA, 2009; Laukkonen et al., 2009). Occurrence of drought cases and low rainfall reduces growth and regeration of vegetation. These may be the reason for dying of animals in the area. Discussions with the local community they kept on referring the method of uncontrolled grazing of cows, sheep, goats and donkeys by their fellow farmers. Uncontolled grazing is the most disastrous factor of LULCC and land degradation.

Local People Perception of Land Management Strategies

The local community proposed similar land management strategies in both Rusinga West and Rusinga East (Table 6). Sustainable land management may be enhanced

Table 6. Perceived land management options in Rusinga Island.

Perceived land management options	Percent	
	Rusinga West	Rusinga East
Planting trees	19.6	21.5
Controlled grazing	15.2	11.8
Controlled deforestation	14.9	18.2
Land use management strategies	16.4	15.7
Governance and land use policies	14.9	15.9
Soil water and conservation	19	16.9
Total	100	100

through planting of trees combined with controlled deforestation and grazing and adoption of farm specific land use management strategies. Planting of trees is still the best strategy of land restoration. Studies such as that of Mapedza et al. (2003) have found that planting of locally adopted tree are key strategies to enhance forest restoration. Majority both in Ruinga West and Rusinga East mentioned that they have adopted trees such as *Acacia seyal*, *Senna simmea*, Prosopis, *Moringa oloifera* and *Mangifera indica* in their homestead and on their farms which they believed were necessary to enhance restoration of vegetation cover in their locality as well as control soil erosion on their farms. Discussions with key informants such as Badilisha Ecovillage Trust explained how they had extended tree planting efforts to both schools and near the forest area.

Controlled deforestation and grazing are long term measures to enhance sustainable land management. The local community mentioned the on-going measure to curb grazing in the forest area to allow regeneration of the forest. They highlighted that establishment of community grazing areas was necessary to manage uncontrolled grazing which was being practiced in the study area. They also mentioned that the use of local forest guard was good initiative but felt the government needed to fence and gazette the forest area in order to mark forest boundary and avoid encroachment into the forest by local community.

Besides, adoption of soil and water conservation practices through establishment of soil contours, diversified planting in farms were highlighted as key to strategic farm management practices for sustainable land management. They stated establishment of contours on the farm was helping to control soil erosion and conserver soil moisture on the farm. They said they adopted this along with different crops. They believed that such measures were necessary to increase farm production and needed support by the government since most people are poor. Studies such as that of Negasi et al. (2018) point out tree planting, soil and water conservation measures and contolled deforestation and grazing are long term measures to control LULCC. Reddy and Gebreselassie (2011) reported that sustainable land management and PGIS with governement officials, community and NGOs were necessary measures in land resource management.

CONCLUSIONS

Participatory GIS analysis revealed major changes in LULC in both locations. In Rusinga West significant changes occurred in forest and settlement area while in Rusinga East changes were significant in forest, settlement and bare areas in the three-time period. Participatory GIS provided the community with a platform to discuss, visualize and map the resources as well observe how they have changed overtime.

Majority in Rusinga West associated LULCC with socioeconomic drivers mainly population increase. Majority in Rusinga East believed the occurrence of LULCC was caused by both socioeconomic and environmental factors including drought, poverty, and excessive charcoal burning and clearing for settlement.

The alarming nature LULCC led to several undesirable effects such as drying of water sources, dying of animals due to shortage of feeds, climate change and reduced crop yield. Sustainable land management in Rusinga Island can be enhanced through planting of locally adapted trees combined with controlled deforestation, grazing and adoption of farm specific soil and water management strategies such as contours. Involvement of local community is necessary to ensure sustainability.

CONFLICT OF INTERESTS

The authors declared that they have no conflict of interest

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REFERENCES

Abonyo CK, Isabirye M, Mfitumukiza D, Magunda MK, Poesen J, Deckers J, Kasedde AC (2007). Land use change and local people's perception of the effects of change in Ssese islands, Uganda. National Agricultural Research Organisation, Uganda 101 p.

Altaweel MR, Alessa LN, Kliskey AD, Bone CE (2010). Monitoring land use: Capturing change through aninformation fusion approach. Sustainability 2(5):1182-1203.

Amare S (2013). Retrospective Analysis of Land Cover and Use Dynamics in Gilgel Abbay Watershed byUsing GIS and Remote Sensing Techniques, Northwestern Ethiopia,. International Journal of Geosciences 4(7):1003-1008.

Anyekulu E, Birhane E, Wubney W, Begashawl N (2006). Monitoring and evaluating land use/land cover change using Participatory Geographic Information System (PGIS) tools: A case study of Begasheka Watershed, Tigray, Ethiopia. The Electronic Journal of information systems in developing countries 25(1):1-10.

Baaru M, Gachene CCK (2016). Community empowerment through participatory resource assessment at Kathekakai settlement scheme, Machakos County, Kneya. International Journal of Sociology and Anthropogy 8(2):15-22.

Bai ZG, Dent DL, Olsson L, Schaepman ME (2008). Global assessment of land degradation and improvement: 1. identification by remote sensing (No. 5). ISRIC-World Soil Information. Available at: https://library.wur.nl/WebQuery/wurpubs/fulltext/40715

Bajocco S, De Angelis A, Perini L (2012). The Impact of Land Use/Land Cover Changes on Land Degradation Dynamics: A Mediterranean Case Study. Environmental Management 49(5):980-989.

Brassoulis H (2000). Analysis of land use change: theoretical and modeling approaches, the web book of regional Science. Regional research institute, West Virginia University, USA.

Campbell DJ (1990). Strategies for coping with severe food deficits in rural Africa: a review of the literature. Food and Foodways 4(2):143-162.

Campbell DJ, Lusch DP, Smucker TA, Wangui EE (2005). Multiple methods in the study of driving forces of land use and land cover change: a case study of SE Kajiado District, Kenya. Human Ecology 33(6):763-794.

Carver S (2001). Participation and Geographical Information: a position paper. In ESF-NSF Workshop, Spoleto, Italy.

Chambers R, Pacey A, Ann TL (1991). Farmer First: Farmer innovation and agricultural research. Intermediate technology publications. London.

Connelly W (1994). Population pressure, labor availability, and agricultural disintensification: The decline of farming on Rusinga Island, Kenya. Human Ecology *22*(2):145-170.

Corbett J (2009). Good practices in participatory mapping. A review prepared for international fund for agriculture (IFAD), Rome, Italy.

CTA (2016). Participatory GIS Practice - Mapping for Change International Conference - Reportage [Motion Picture].

De Graff J (1993). Soil conservation and sustainable land use: An economic approach.

Di Gessa S (2008). Participatory mapping as a tool for empowerment: Experiences and lessons learned from the ILC network. Rome: International Land Coalition.

Gamble J, Simpson C, Baer M, Baerwald T, Beller-Simms N, Clark R, Eavey C, Gant M, Hickman C, Hohenstein B, Houghton J (2003). Human contribution and responses to environmental change. Strategic Plan for the US Climate Change Science Program, CCSP, Washington, DC, USA pp. 93-100.

Geist H, William M, Eric FL, Emilio M, Diogenes A, Thomas R (2006). Causes and trajectories of land use-cover/change. Land use and land cover change pp .41-73.

Gessesse B, Bewket M (2014). Drivers and Implications of Land Use and Land Cover Change in the Central Highlands of Ethiopia: Evidence from Remote Sensing and Socio-demographic Data Integration. Ethiopian Journal of Social Science and Humanities 10(2):1-23.

Hosonuma N, Martin H, Veronique DS Ruth SDF, Maria B, Louis V, Arild A, Erika R (2012). Assesment of deforestation and forest degradation drivers in developing countries. Environmental Research Letters 7(4):044009.

intergovernmental panel on climate change (IPCC) (2012). Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change. Cambridge University Press.

Jaetzold R, Schmidt H, Hornetz B, Shisanya C (2005). Farm Management Handbook of Kenya, Volume II. Nairobi, Kenya: Ministry of Agriculture.

Jalilova G, Vacik H (2012). Local people's perceptions of forest biodiversity in the walnut fruit forests of Kyrgyzstan. International Journal of Biodiversity Science, Ecosystem Services and Management 8(3):204-216.

Johansson EL, Isgren E (2017). Local perceptions of land-use change: using participatory art to reveal direct and i indirect socioenvironmental effects of land acquisitions in Kilombero Valley, Tanzania. Ecology and Society 22(1):3-12.

Kathumo VM, Gachene CKK, Okello JJ, Ngugi M, Miruka M (2012). Is Lower Tana River Forest Complex and Ecosystem under Threat of Total Destruction? Evidence from Participatory GIS. In Zainabu Khalif, Charles KK Gachene, Patrick Gicheru, David Mwehia Mburu, Christopher Gatama Gakahu (Ed), Sustainable Land Management in Dry Lands of Kenya: Improving land productivity through participation Research and Technology Transfer pp. 26-48.

Kenya National Bureau of Statistics (KNBS) (2019). 2019 Kenya Population and Housing Census. Nairobi.

Kindu M, Schneider T, Teketay D, Knoke T (2015). Drivers of land use/land cover changes in Munessa-Shashemene landscape of the south-central highlands of Ethiopia. Environmental Monitoring and Assessment 187(7):1-17.

Lambin EF, Helmut JG, Erika L (2003). Dynamics of land use and land cover change in tropical regions. Annual review Environmental Resources 28(1):205-241.

Lambin EF, Turner BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, George P (2001). The causes of land-use and land-cover change: moving beyond the myths. Global Environmental Change 11(4):261-269.

Laukkonen J, Blanco P, Lenhar P, Keiner M, Cavric B, Kinuthia NC (2009). Combining climate change adaptation and mitigation measures at the local level. Habitat International 33(3):287-292.

Le QB, Nkonya E, Mirzabaev A (2014). Biomass productivity-based mapping of global land degradation hotspots. Economics of land degradation and improvement–A global Assessment for Sustainable Development Chapter 4, pp. 55-84.

Leemans R, De Groot RS (2003). Millennium Ecosystem Assessment: Ecosystems and human well-being: a framework for assessment. Available at: https://library.wur.nl/WebQuery/wurpubs/326575

Malaki PA, Kironchi G, Mureithi S, Kathumo V (2016). Assessing Land Use and Land Cover Change Using Participatory Geographical Information System (PGIS) Approach In Nguruman Sub-Catchment, Kajiado North Sub County, Kenya. Journal of Geography and Regional Planning 10(8):219-228.

Mapedza E, Wright J, Fawcett R (2003). An investigation of land cover change in Mafungautsi Forest, Zimbabwe, using GIS and participatory mapping. Applied Geography 23(1):1-21.

McCall MK, Minang PA (2005). Assessing participatory GIS for community-based natural resource management: claiming community forests in Cameroon. Geographical Journal 171(4):340-356.

Ministry of Environment and Natural Resources (2016). Land Degradation Assesment in Kenya. Narobi. Available at:

http://www.environment.go.ke/wp-content/uploads/2018/08/LADA-Land-Degradation-Assessment-in-Kenya-March-2016.pdf

MoA (2009). Participatory rural appraisal report. Katheka-kai location, Central Division, Machakos District.

Negasi S, Hishe H, Annang T, Pabi O, Asante KI, Birhane E (2018). Forest cover change, key drivers and community perception in Wujig Mahgo Waren forest of northern Ethiopia. Land 7(1):32.

Odimegwu C (2000). Methodological issues in the use of focus group discussion as a data collection tool. Social Science 4(2-3):207-212.

Odula E (2019). Land use and land cover changes in Rusinga Island, Personal communication. (S. Wekesa, Interviewer).

Perez M (2003). Participatory GIS Approach for Mapping Land Use Change and Assessing Associated Effects of Those Changes in a Watershed: A Case Study in Laelay Wukro, Tigray Region, Ethiopia. MSc. Thesis, National University of Ireland, Cork.

Rambaldi G (2004). Summary proceeding of the Track on international PGIS perspective. Third Internaional Conference on Public Participation GIS (PGIS), University of Winscosin-Madison,, (18-20). Madison, Winscosin, USA.

Rambaldi G, Corbett J, Olson R, McCall M, Muchemi J, Kyem PK, Weiner D, Chambers R (2006). Mapping for change: practice, technologies and communication. Participatory Learning and Action 54:1-13.

Rambaldi G, Kyem PAK, McCall M, Weiner D (2006). Participatory spatial information management and communication in developing countries. The Electronic Journal of Information Systems in Developing Countries 25(1):1-9.

Reddy TB, Gebreselassie MA (2011). Analyses of land cover changes and major driving forces assessment in middle highland Tigray, Ethiopia: the case of areas around Laelay-Koraro. Journal of Biodiversity and Environmental Sciences 1(6):22-29.

Sakimba K (2016). Resources change dynamics and their impications for pastoral livelihoods in Amboseli ecosystem, Kenya. Masters thesis. University of Nairobi, Kenya.

Sombroek WG, Braun HMH, Van Pouw BJA (1982). Exploratory soil map and agro-climatic zones map of Kenya. Nairovi, Kneya: Kenya Soil Survey.

Suba District Development Plan (Suba DDP) (2008). Ministry for Planning, National Developm ent and Vision 2030.

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

Toh FA, Angwafo T, Ndam LM, Antoine MZ (2018). The socio-economic impact of land use and land cover change on the inhabitants of Mount Bambouto Caldera of the Western Highlands of Cameroon. Advances in Remote Sensing 7(01):25-45.

Trudgill S (2014). The Terrestrial Biosphere: Environmental Change, Ecosystem Change, Attitudes and Values: (Vol. 57). New Zealand.

Turner BL, Lambin EF, Reenberg A (2007). The emergence of land change science for global environmental change and sustainability. Proceedings of the National Academy of Sciences 104:20666-20671.

Waswa BS (2012). Assessment of land degradation patterns in western Kenya: Implications for restoration and rehabilitation (Doctoral dissertation, Universitäts-und Landesbibliothek Bonn).

Worku M, Deribew S (2018). The cause of land-use change and effect of the change on crop yield in case of Azezo Tekle Haymanot Kebele. Journal of Agricultural Science and Food Research 9(1):1-8.

Zurayk R (2003). Participatory GIS-based natural resource management: Experiences from a country of the South. Aridlands Newsletter No 53.