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Land Use-Land-Cover Changes in Saiwa Swamp Watershed, Western Kenya

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Abstract: *Changes in land use-land cover (LULC) affect ecosystems, biodiversity and goods and services that ecosystems provide to society. Information on changes in land use-land cover is in crucial delineating impacted areas, understand the type of changes, their spatial patterns and impacts. The magnitude of change varies with time period examined as well as the geographical area. The study focused on the Saiwa Swamp watershed in western Kenya which has mixed farming and with one of the smallest conservation areas, the Saiwa Swamp National Park (3 km^2). Results from the study show significant land use-land cover changes have taken place in the watershed in the last 3 decades since 1985. Although built-up and riparian areascovered about 0.46% and 0.81% of the watershed, they showed significant increase and a decline respectively. These LULC changes were largely attributed to socio-economic drivers including population increase and extensive agriculture. There is hence need to strengthen law enforcement on physical planning in order to reduce encroachment of natural areas such as forests and riparian zones. The study also recommends further assessment and monitoring of spatial and temporal based land use-land cover changes in Kenya.*

Keywords: *Saiwa Swamp watershed, land use-land cover, riparian.*

1. Introduction

Land use activities have altered a large proportion of the planet's land surface. Although land use practices vary greatly across the world, their ultimate outcome is the way they alter the structure and functioning of ecosystems. Due to the significance of such changes on the biosphere, monitoring changes in land use-land cover is a high priority area for research (De Fries *et al.,* 2007). Quantifying land transformation is essential in understanding and modelling of complex interactions and impacts between the natural and human environments, from local, regional to global scales. Multi-temporal analyses of land use-land cover changes provide important insights into long term trends which serve to identify the drivers and determinants of these changes (De Fries *et al.,* 2007).The most significant changes in land use are related to agricultural expansion resulting in decrease in natural vegetation formations such as forests, bush lands, grasslands and wetlands (Githui *et al.,* 2009). These changes are a result of the increasing human population and increased demand for ecosystem goods and services. While these significant changes in land use-land cover have allowed sustained human population growth and economic development in the past, it raises concerns regarding local and regional environmental impacts and their consequences on human well-being and environmental quality.

Improved understanding of local to regional land use change and its negative environmental impacts lead to the formulation of sustainable development planning. One of the most important aspects of interpreting ecosystem status is timely information on land use-land cover change (Turner *et al.,* 2007). Activities, such as farming, deforestation and expansion of urban areas, taking place within many watersheds greatly affect the status of wetlands as much of the runoff drains directly into these water bodies. This can lead to increased levels of sedimentation and pollution of water bodies due to the reduction in wetland buffer zones (Kipkorir, 2017). Kenya has very few wetlands available due to encroachment by agricultural and other human activities. In the end, this has led to reduction in biodiversity and ecosystem goods and services supplied by these ecosystems. However, few studies have been carried out in Kenya on how these types of activities taking place within a watershed affect wetlands.

Saiwa Swamp, one of the most critical wetlands in Kenya,is situated in a watershed that is experiencing increasing human population pressure, especially due to farming activities. The Saiwa watershed, located about 400 km west of Nairobi and is home to an endemic and endangered small population of semi aquatic antelope Sitatunga (*Tragelaphalus spekei*) whose wetland habitats are threatened by intensive agricultural practices.

The aim of the study was to map and elucidate the changes in the main land cover types within the Saiwa Swamp National Park watershed occasioned by human activities over the last few decades.

2. Materials and Methods

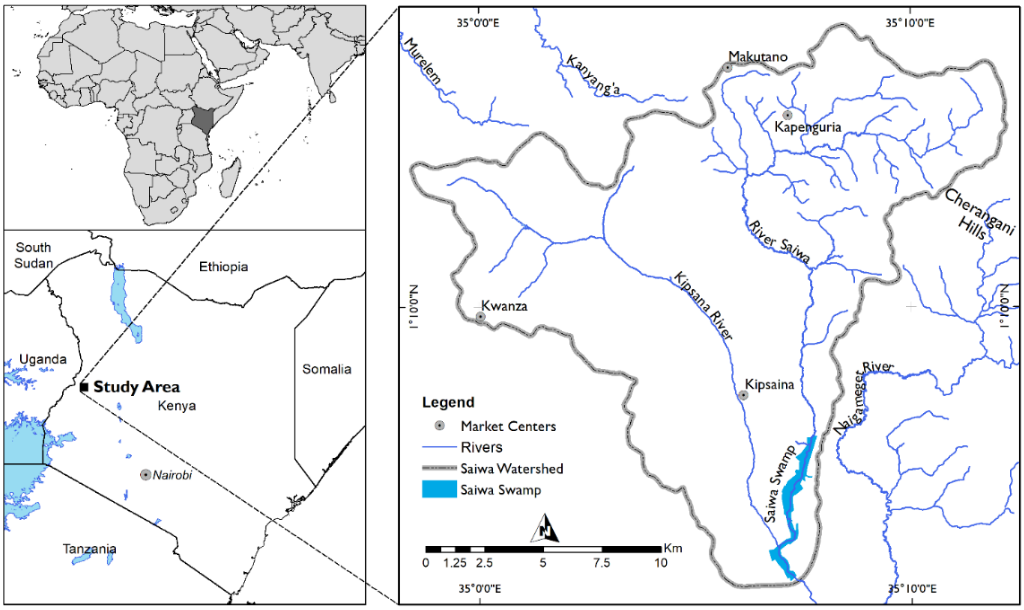

Figure1. *Location of the study area (Saiwa Swamp Watershed)*

Saiwa watershed, is situated in western Kenya. It is bounded by latitudes 1.1° and 1.3° and longitudes 35.0° and 35.2° (Figure 1). The watershed is drained by Saiwa and Sitatunga rivers that feed the Nzoia river system which flows into Lake Victoria. The watershed boundaries were derived from Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) version 2with 30m spatial resolution that delineated an area of about 27,500 hectares.

To estimate the human population changes during the inter-census periods (1979, 1989, 1999 and 2009), population projection method by Weeks (1999) was used. Soil maps of the study area were sourced from the Kenya Soil Survey and the Lake Basin Development Authority. The sheets were scanned, geo-referenced and digitized. Pre-processed Land sat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI) top-of-atmosphere reflectance, orthorectified scenes were obtained from the USGS through Google's Earth Engine. These scenes were classified as level 1 terrain corrected products (L1T) that offer acceptable levels of spatial accuracy, therefore no geo-rectification was required and image-to-image registration was omitted as described by Chander *et al.* (2009). Composite images were processed using available Landsat images for the years of 1985, 1995, 2000, and 2015.

Six land cover classes were selected to capture the main landscape variability based on visual interpretation of Landsat scenes and Google/Bing maps VHR imagery and through on the ground visits to the area. Images from multiple seasons and years were used for choosing training sites for periods older than 2000.Machine-learning techniques, including Classification and Regression Trees (CART) and Random Forest (RF) were used (Gislason *et al.*, 2006). Changes in land cover between 1985 and 2015 were determined using a supervised classification method that uses random forest technique in R environment. In order to minimize errors in land cover classification, majority analysis using kernel size of 3 by 3 was employed to change spurious pixels within a large single class and smoothing the land cover results. The accuracy of the land cover classification was assessed using a confusion matrix to compare the classification results to the ground observation using the Kappa statistic (Congalton and Green, 1999). From the Confusion matrix, predictions were 79% (1985), 84% (1995 and 2000) and 81% for 2015 while Kappa coefficient values were 0.732, 0.792, 0.790 and 0.746 for years 1985, 1995, 2000 and 2015 respectively.

3. Results and Discussion

3.1. Soils

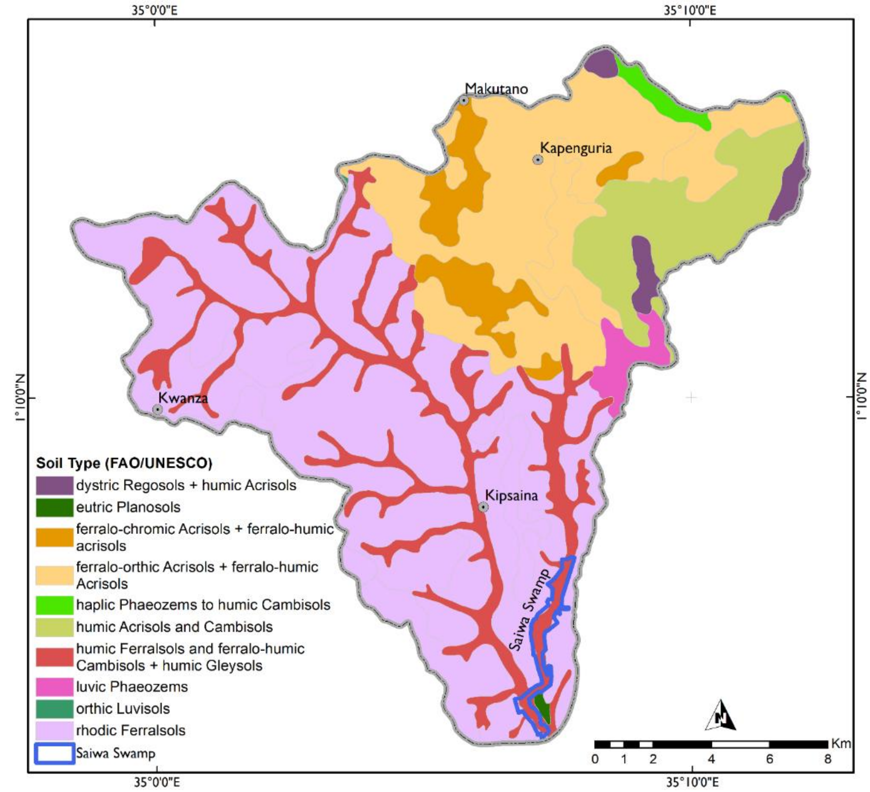

Figure2. *Soil map of Saiwa Swamp Watershed*

Table1. *Soils and their areal cover in the Saiwa Watershed*

Soil Type	Area (ha)	% Cover
Dystric Regosols + Humic Acrisols	453.71	1.65
Eutric Planosols	36.10	0.13
Ferralo-Chromic Acrisols + Ferralo-Humic Acrisols	1351.89	4.91
Ferralo-Orthic Acrisols + Ferralo-Humic Acrisols	5983.96	21.72
Haplic Phaeozems to Humic Cambisols	249.58	0.91
Humic Acrisols and Cambisols	2355.71	8.55
Humic Ferralsols and Ferralo-Humic Cambisols + Humic Gleysols	3755.81	13.63
Luvic Phaeozems	447.35	1.62
Orthic Luvisols	7.36	0.03
Rhodic Ferralsols	12910.88	46.86

The results showed that the watershed was composed of different soil types (Figure 2). The relative proportion of each soil type is presented as a percentage in Table 1. Rhodic Ferralsols soils are the most common type occupying 46.86% of the study area followed by Ferralo-orthic Acrisols + ferralo-humic Acrisols at 21.72% while Gleysols occupy 13.63%. Small pockets of Eutric Planosols and haplic Phaeozems to Humic Cambisols occur in the hilly and steep slopes of the area north of Kapenguria which are developed form Basement System rocks, predominantly gneisses, and are excessively drained to well drained, shallow, friable, sandy, clay loam to clay and in many places are rocky, boulderly and stony (Jaetzold and Schmidt, 1983) with humic top soils making them to have serious farming problems.

Ferralsols are a complex of well drained acidic soils, shallow to deep, dark red to strong brown, friable gravelly sandy clays to clays, developed from intermediate igneous rocks (phonolites, syenites and trachytes). Most of the soils in the catchment area are acidic and of moderate to low soil fertility except for some parts around Kwanza and the river valleys (Jaetzold and Schmidt, 1983). In Kenya, acid soils are found in areas of high rainfall, and are particularly low in available P and N, making themthe major causes of low and declining crop yields (Kanyanjua *et al.*, 2002). Soils in the high agricultural potential zones have continued to lose their fertility as a result of a number of factors including mono cropping, inadequate inorganic and organic fertilizer use, and continuous tilling and soil erosion.

3.2. Population Dynamics

The total population of Saiwa watershed increased at a rate of 11.8 per cent per year from about 72,585in 1999 to 91998in 2009 census periodsa rate that is above the national growth rate of 2.5%. Increase in population resulted in a shift of population density from about 200 inhabitants/km^2 in 1999 to 254 inhabitants/km^2 in 2009 (GoK, 2009). This increase in population has negative implications on the sustainability of the watershed through activities such as deforestation, soil erosion and depletion of natural resources. Increase in population has other underlying effects such as the interference of water course-ways and loss of the more adaptable indigenous vegetation which has the capacity to withhold water (Kithiia, 2006). Work by Sahin and Hall (1996) shows that the surface run-off and river discharge increase when natural vegetation is cleared or degraded, triggering extreme flooding events and soil erosion.

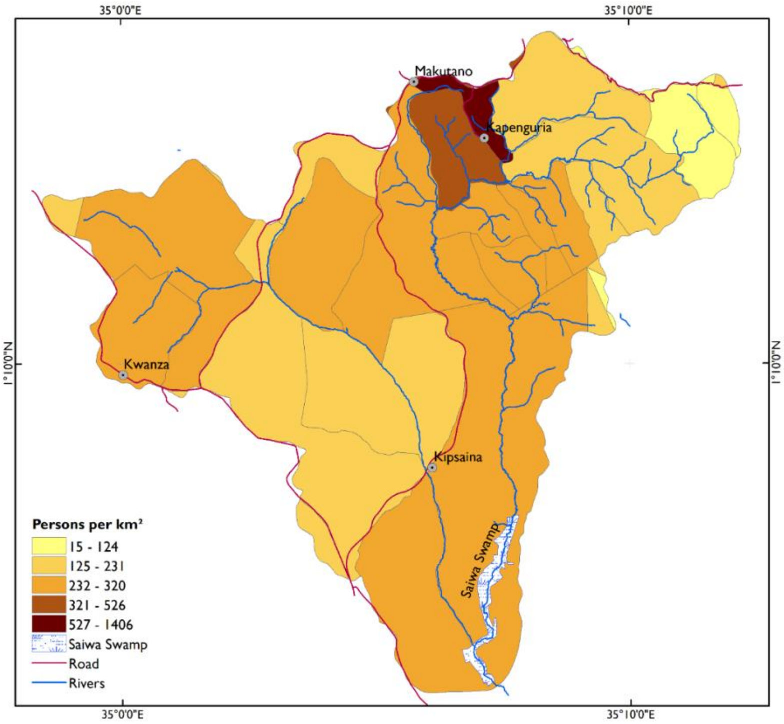

Figure3. *Population Density of the Saiwa Watershed based on 2009 Census*

Like in many parts of the developing countries, the increase in population in the watershed, resulted in increase in urbanization as is evident in areas close to market places, such as Kapenguria and Makutano that are now surrounded by higher densities of human populations than farmlands (Figure 3).

Some of the factors that influenced population change in the watershed include human immigration, fragmentation of large former colonial farms to small scale farms following the formation of resettlement schemes (Cone and Lipscomb, 1972).Majority of the immigrants moved into the area between 1960 and 1970 and their numbers have since increased due to more and more immigration and population increase through natural births (GoK, 1989). The other factor is the general changes in land use policies in Kenya. Before the colonial era, land had been zoned into specific areas for specific crops depending on rainfall variability (Cone and Lipscomb, 1972), which is no longer followed.

3.3. Land Use-Land Cover Changes

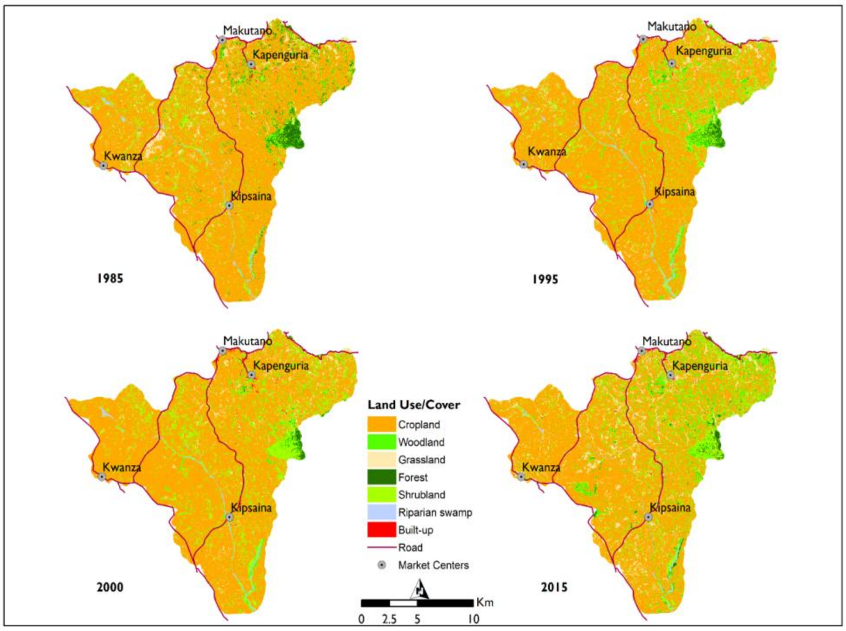

Figure4. *Land Cover Classifications for 1985, 1995, 2000 and 2015*

Table2. *Land use-land cover distribution*

Land use-land cover	Period in Years							
	1985		1995		2000		2015	
	Area (ha)	% Cover	Area (ha)	% Cover	Area (ha)	% Cover	Area (ha)	% Cover
Cropland	20,632	74.89	20,133	73.11	20,791	75.53	18,013	65.43
Woodland	661	2.40	1,188	4.31	739	2.68	2,112	7.67
Grassland	1,581	5.74	1,442	5.24	1,048	3.81	2,464	8.95
Forest	840	3.05	252	0.92	148	0.54	318	1.15
Shrubland	3,554	12.90	4,201	15.26	4,453	16.18	4,269	15.51
Riparian	195	0.71	222	0.81	191	0.70	130	0.47
Built-up areas	87	0.32	99	0.36	157	0.57	223	0.81

The status of each land-use-land cover type between the period 1985 and 2015 are shown in Figure 4. These results show that there were notable changes in land cover especially for forests, woodlands and cropland. The majority of the watershed was covered by cropland followed by shrubland while the riparian and the built up areas had the least cover respectively. The area under crops between 1985 and 2000 remained almost the same showed a sharp decline between 2000 and 2015 from 75.53% in 2000 to 65.43% in 2015, a decline of 10% (Table 2). No clear reasons can been given as the driving force for this decline, but it is postulated that one major reason was the conversion of cropland to other land uses, including to built-up areas due to urbanization resulting from increased population among others (Bilsborrow and Okoth-Ogendo, 1992). During the pre-colonial period (before 1963), large scale farming was more dominant and was later replaced by the small scale farming following land sub-division after Kenya's political independence in 1963. Settlement schemes which were created after independence to resettle landless people saw a lot of sub-division that attracted more immigrants into the area. This resulted in more land getting converted into smaller farm units leading to reduced overall farmland cover. The findings of this study are in agreement with those of Bilsborrow and Geores (1991), who found that human population growth positively correlates with land use intensification, expansion of built-up areas and deforestation in many developing countries.

Another factor that can closely be linked to the decline in cropland cover is the establishment of woodlots. It was observed that the shrinking area under crops correlates closely with the increasing area under woodlands mainly due to improved establishment of woodlots, through planting of exotic trees such as eucalyptus, Wattle trees and cypress which grow faster than the indigenous tree species and had high economic returns. This may have further been boosted by the government policy on tree planting. Examples of extensive woodlots were especially noted in Kwanza and Cherangany sub-counties of Trans Nzoia County and Kapenguria in West Pokot County.

There was a notable increase in woodland between 1985 and 1995 from 2.40% to 4.31% respectively. However, between 1995 and 2000, woodland cover declined from 4.31% to 2.68% and thereafter increased sharply from 2.68% to 7.6% between 2000 and 2015 respectively.

Grasslands cover remained almost the same between 1985 and 1995 but declined between 1995 and 2000 from 5.25% to 3.81% before sharply increasing from 3.81% to 8.95% between 2000 and 2015. The initial decline of grassland cover could be attributed to the drought that was experienced between 1984/1985 and the conversion of grasslands to farmlands and woodlands through agro forestry practices. The increase in grassland cover between 2000 and 2015 could also be linked to enhanced fodder farming due to increased dairy farming in the area (Kipkorir, 2017).

Forest cover declined sharply from 3.05% to 0.54% between 1985 and 2000. However, forest cover increased sharply from 0.54% to 1.15% between 2000 and 2015. This sharp increase can be linked to increased planting of woodlots following the government policy of tree planting in order to attain the 10% forest cover as required by the United Nations (FAO, 2006).

There were no notable major changes in shrubland area between the years 1985 to 2015. The relatively stable state of shrubland cover could be attributed to the nature of this vegetation type. In East Africa, shrublands are described as plant communities characterised by vegetation dominated by shrubs, which may either occur naturally or as a result of human activity (Pratt and Gwynne, 1977). Simute (1992) found that shrublands remain in their stable state due regular natural disturbance such as fire and browsing. Shrublands in our study were mostly found in the northern part of the study area where the mainstay activity is raising of pastoral livestock especially sheep and goats.

For the riparian zones, the trend in change was similar to that of croplands and remained almost the same between 1985 and 2000 but declined by about 30% between 2000 and 2015. This decline can be attributed to encroachment of the riparian land by farmers for growing of vegetables and horticultural crops.

Built up areas showed a change of 125% between 1995 and 2015.Although our findings show that built-up environment was one of the land uses with minimal percentage cover, it was nonetheless on an upward trend and this could be explained by the general increase in urbanization; emergence of new markets along the roads and the general increase in settlement in response to population growth as observed around Kapenguria and Makutano.

According to Collins (2006), developing countries, especially in Africa have the highest rate of rural to urban migration in the world. Africa has an urbanization rate of 4.87% as opposed to 2.57% for the world. The overall growth rate of Kenya's urban population stands at 6% implying very rapid rural to urban migration pattern (GoK, 2009). Much of this rural to urban migration is influenced by economic growth and development, technological change (Marshall *et al.,* 2009) and sometimes also by conflicts and social disruptions.

In general, the possible forces driving land-use and land-cover changes can be grouped into six categories namely population increases, technology changes, political economy, political structure, attitudes and values (Meyer and Turner, 1992; Stern *et al.*, 1992). Political economy includes the systems of land exchange, ownership, and control while political structure involves institutions and organization of governance on land ownership. Although not all of these factors have a direct effect in the study area, population change, technology and political economy and structure may have greatly influenced land-use and land-cover in the study area.

In Kenya, the most significant changes in land use-land cover are related to agricultural expansion resulting in decrease in natural vegetation formations such as forests, bush lands, grasslands and wetlands (Githui *et al.,* 2009). These changes are a result of the increasing human population and increased demand for food and fuel wood. While these changes have allowed to sustain human population growth and economic development in the past, it raises concerns regarding negative local and regional environmental impacts and their consequences for future human well-being.

Results from the present study show significant land use-land cover changes have occurred in the Saiwa Swamp watershed during the past four decades. Total population also exhibited positive growth mainly as a result of immigration and natural increase. By processing and comparing multi-sensor Landsat scenes over five time intervals between 1985 and 2015 in Saiwa Swamp watershed, we observe an overall trend towards a reduction in shrub/riparian vegetation extent to agricultural land. Other observed land cover transition processes are succession of agricultural land to built-up area and farm woodlots. Saiwa and the neighbouring swamps are the sources of domestic and small-scale irrigation water for horticultural farming. However, the increasing human activities are threatening their ecology. The results of this study, show that there is need to strengthen the enforcement of laws governing physical planning in order to reduce encroachment of natural areas such as forests and riparian zones. The study also recommends further assessment and monitoring of spatial and temporal based land use-land cover changes.

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