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Assessment of the Land Use/Land Cover Change in Koitobos River Catchment, Trans Nzoia County, Kenya

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ABSTRACT

Globally, many countries are facing pressure to meet the livelihood needs of their fast-growing populations. This often leads to overuse of natural resources and consequent encroachment on fragile ecosystems such as river catchments and riparian areas mostly in developing countries. The objective of this study was to assess the implication of land use, land cover changes on surface water acreage in the Koitobos River catchment. Specifically, the study assessed the extent of land use/land cover changes with data being based on Landsat images pertaining to the period of study, 1992 - 2022. The research design used was correlations where the Google Earth Engine (GEE) and Remote sensing techniques were used for the analysis with in-depth review of journals and research reports. A sample size of 384 respondents, according to Krejcie, & Morgan as drawn from a target population of 203,821 residents within the study area. The survey data was analyzed using SPSS software version 25 and the Microsoft excel. The results were presented in form of frequencies, charts, maps, and tables. The findings of Land Use/Land Cover Change for the years 1995, 2009 and 2022, showed that Agricultural Land covered most of the study area with a cover of 26,853Ha, (58%), 32,438 Ha (70%), and 36,118Ha (77.68%) respectively. When transitioning through the years, thus shows drastic increased changes in area. This was followed by bare land area which covered an area of 14,915 Ha (32%), 8,093 Ha, (17%) and 6175 Ha (13.28%) for the years 1995, 2009, and 2022 respectively, of the entire catchment area which extremely decreased transitionally as the agricultural land increased due to the pressure exerted on the resource. The forest land showed a drastic decreasing trend through the transitional period from a cover of 2242 Ha (5%) to 1647 Ha (4%) and then 222 Ha (0.48%), due to an increasing demand for space by the growing population as depicted by the Kenya National Bureau of Statistics (KNBS) reports, which increasingly resulted to deforestation activities. The coverage for the agricultural land in the years 1995, 2009, and 2022 spread all over the area separated by patches of bare lands, water, and forests. The population of the study area in 2009, was 166,524 persons and 203,821 persons in 2019, within an area of 465.3 square Kilometers with residents' density of 438.0 per square kilometer. The study found out that due to a 2% (percent) annual population change over the period 2009 to 2019, this resulted in an increased demand for food production and therefore concluded that environmental policies and laws needed to be adopted together with sustainable land management practices for healing and conserving biodiversity in Koitobos river catchment. The study therefore recommended the adoption of sustainable land use management practices that continually have the potential to heal the land and conserve biodiversity in Koitobos river catchment.

Key Words: Biodiversity, Catchment Area, L and Use, L and Cover Change, Surface Water Acreage, Restoration

I. INTRODUCTION

Marhaento et al. (2017) conducted a study on the attribution of changes in stream flow to land use change and climate change in a meso-scale tropical catchment in Java, Indonesia. The study highlighted the impact of land use and land cover changes on the river catchment and surface water. Changes in forests, arid agriculture, and urban areas were the most significant factors influencing surface runoff. In a previous study, it was determined that logging action could affect the impact of the 100-year return period rain and land use evaluation within a specific period. This evaluation was necessary to identify trends in natural change that could be used to address future mitigation requirements. (Guan et al., 2016)conducted a study on the relationship between rainfall patterns and runoff response. (Mzuza et al., 2019) investigated the changes in land use and land cover of the middle Shire River catchment in Malawi, southern Africa, over a 26-year period. They employed geographic information systems (GIS) and remote sensing techniques to determine that the rate of deforestation was high, with an average annual increase of 4.3%.

Deforestation and forest degradation are caused by human activities such as expanding metropolitan areas, clearing large areas of land for agriculture, and harvesting trees for energy purposes (Zegeye, 2017). These processes are fueled by rising populations and Gross Domestic Product (GDP). Severe issues with land use/land cover changes were caused by the deforestation in the middle Shire River basin, which was related to increased soil loss through erosion. This led to massive silt accumulation downstream. People in the catchment had no alternatives from cutting down trees for charcoal as a means of subsistence due to the devastating impact of frequent floods and droughts on crop output caused by irresponsible land management (Nyariki, 2002). Thus, other locations where comparable problems do arise could benefit from applying the integrated methodologies utilized in this study, which included geographic information systems (GIS), remote sensing, and socioeconomic considerations.

Based on studies by (Kogo et al., 2020) vegetation plays an important role in protecting soil from erosion, Consequently, accelerated soil erosion could lead to watershed degradation whereby there is loss in litter production, organic matter accumulation, and root growth. Borrelli et al., (2020) believed, changes in LULC and its dynamics were closely associated with human activities and increasing demand for settlement and Agricultural production imposes a threat of land degradation. The Analysis of efforts and underlying causes of forest cover change in the various forest types of Kenya, done by (Rotich & Ojwang, 2021), showed that agricultural expansion and harvesting or extraction of wood for charcoal, firewood are the most dominant direct drivers of forest cover loss in Kenya.

At present, extraction of wood for charcoal and firewood are pre-dominant, particularly in the arid and semi-arid woodlands. In their studies on effects of deforestation on Water Resources, Rodríguez-Romero et al., (2018) showed that the longitudinal deterioration in water quantity in rivers reflected the cumulative effects of human activities both on the riparian and in the catchment areas. Hua, (2017), (Camara et al., 2019) and James et al., (2019) corroborated this finding by confirming that this phenomenon has been reported in several studies conducted to investigate the influence of land use and water quality in rivers in the region. (Zaimes et al., 2019) were of the view that, turbidity increase downstream mainly originates from agricultural areas and erosion from unpaved roads. Previous studies on rivers had also indicated that the water quality can deteriorate because of the intensification of agricultural activities and clearing of forests. Agricultural expansion for subsistence and commercial farming remains key drivers in land use / land cover change in the upper Nzoia River basin resulting to both degradation and deforestation.

Research assessing the effects of alterations in land use on hydrological responses in the Koitobos river basin demonstrated that significant land use changes had occurred in the area over the last 150 years, starting from the conditions prior to human settlement. The study examined the changes occurring in the region, including the significant deforestation, depletion of wetlands and rangelands, which had been replaced by agricultural activities and urban development. Guzha et al., (2018) found that land use change has a significant impact on several land surface features and processes, such as leaf area, roughness, albedo, soil moisture, energy, and water vapor exchange rates. Land use changes, such as urbanization, deforestation, and reforestation, have ongoing impacts on the interactions between groundwater and surface water.

These changes affect processes like percolation or recharge, the contribution of groundwater to streams, soil moisture, and water availability, all of which influence ecosystem services. (Zaimes et al., 2019) conducted research on land use on the slopes of Mt Elgon, which revealed that land use and land cover were characterized by a conflict between conservation measures and subsistence cultivation. In recent times, the area had experienced frequent occurrences of landslides and floods, which had been triggered by heavy rainfall and the deterioration of land quality. These natural disasters resulted in loss of life and significant damage to property. The region possesses a diverse range of living organisms, which have a significant impact on the lives and economic activities of numerous individuals by providing valuable ecosystem services and products. Over the past three decades, large areas of forest reserves had been officially “de-gazetted” and in addition, unofficially converted to other uses, mainly agriculture, and the remaining protected indigenous forests managed by Kenya Forest Services (KFS) and Kenya Wildlife Services (KWS) had been degraded by decades of logging, both legal and illegal, of valuable timber trees resulting in reduced carbon stocks and degraded biodiversity values. Forests on community trust lands under the control of local authorities continued to be degraded and destroyed through over-exploitation for timber, poles, charcoal, fuel wood and through unregulated grazing and clearance for agriculture; depicting what (Hardin, 1968)calls the “tragedy of the commons”.

1.1 Statement of the Problem

Despite efforts to manage the ecosystem, land use/land cover changes and its implications in the Koitobos river catchment in Trans Nzoia County have not been assessed for better development planning towards achieving environmental sustainability, and thus not been undertaken by other researchers in the study area. The essence of this study was therefore to investigate the extent of land use land cover changes in the Koitobos river catchment of Trans Nzoia County in Kenya.

Changes in land use and land cover have far-reaching effects on ecosystems and livelihoods around the world. (Lambin et al., 2006) stated that these changes have significant local, regional, and global consequences for issues like increased soil erosion, disturbances in hydrological cycles, and biodiversity loss on a global scale. According to Sultan (2016) who reviewed research on the effects of interest groups and agricultural expansion on deforestation on a local scale, land degradation processes, soil erosion, microclimatic resources, watershed runoff, and the livelihoods of local societies were all directly affected by changes in land use and land cover. Furthermore, Few et al., (2015) in their study on vulnerability and adaptation to climate change in semi-arid areas in east Africa, which is in line with the Agricultural Sector transformation and growth Strategy (ASTGS, 2019- 2029) Kenya has only 22 % arable land where most intensive crop and dairy production take place, while the rest of the land is arid and semi-arid lands (ASALs). In reference from the Agricultural Water Policy review 2018, this arable land uses 76% of water from all water resources but the water volumes are constantly reducing in rivers and other water bodies due to land use and land cover change activities.

Mt. Elgon and Cherangani ecosystems are both national and international watersheds, which support economic and ecological sectors, yet they are seriously degraded due to land use change from forest to agriculture resulting to decreased water discharge and acreage. Water quantity has drastically dropped or decreased most gauges in the catchment area resulting to challenges with water allocation because some rivers like Chepchoina, Kiptogot, Mubere which are tributaries of Koitobos river have little reserve flow. Thus, water conflicts being reported daily to water officers. This problem stem from the abuse and poor management of forests and soils, overgrazing, extension of settlements into watershed areas, and unsuitable felling of trees for fuel wood. In an assessment of Land Use and Land Cover Changes in Kenya’s Mt. Elgon Forest Ecosystem, (Masayi et al., 2021) registered a significant reduction in forest cover since independence from 10% to 1.62 % because of land use change.

(Ayuyo & Sweta, 2014) also validated these assertions that when the forest cover is reduced to almost zero there is an increased peak and mean stream flow in the basin, Land cover change analysis show that the agricultural area increased from about 39.6% to 64.3% between 1973 and 2001, while forest area has decreased from 12.3% to 7.0%. Considering the above-mentioned problems, it is therefore imperative to understand the hydrological processes occurring within the watershed.

1.2 Research Objective
To assess the extent of land use, land cover change in Koitobos river catchment of Trans Nzoia County Kenya.

1.3 Research Question
What are the land use land cover change categories in the study area?

II. LITERATURE REVIEW

2.1 Theoretical Review
2.1.1 Land Use Change Processes and Middle Range Theories
Theories of land use change processes include land use spillovers, such as land sparing and rebound effects, and land use transitions, such as forest transitions. Middle-range theories are contextual generalizations that describe causal mechanisms and the conditions that trigger them. These theories can help build generalized knowledge of land systems and support sustainable social-ecological systems. Land use economics is a field that studies the relationship between land use, transportation, and economic activities in urban areas. It analyzes how households, developers, and landlords make decisions based on economic principles (Tekola et al., 2012).. Land-use change models are tools to support analyses, assessments, and policy decisions concerning the causes and consequences of land-use dynamics; by providing a framework for the analysis of land-use change processes and making projections for the future land-use/cover patterns and these are in line with the study undertaken on land use /land cover changes in Koitobos River catchment.

The land cover classes of dense forest and barren were found to be constantly decreasing, while the land cover class of open forest was found to be constantly increasing, according to a study of land use and land cover changes in the Harenna forest and adjacent area, Bale Mountains National Park, Oromia National Regional State. The change in dense forest was because of crop production, logging, grazing, and coffee production activities, which decreased the forest density. Logging, resulting from selective cutting of suitable forest trees for timber production, decreases forest density (Cazzolla Gatti et al., 2015). In case of coffee production, there was intensive thinning of forest canopy to optimize the shading. In addition, there was livestock that used to graze the area, causing damage on under vegetation of forest. These practices, apart from change in density, had great impact on biodiversity and the wildlife habitat through changing forest cover resulting to the decrease in bare land due to conversion into agricultural and shrub land. A study to assess the impact of land cover change in Kenya using remote sensing and hydrologic modeling on upper Njoro watershed over several decades in 1986, 1989, 2000, and 2003 which after successful simulation in this environment with land cover change analysis showed a significant loss in upland forests, primarily due to the removal of plantation forests and in addition, a large increase in small-scale agriculture (Baldyga et al., 2004).

Deforestation and cultivation alter the soil hydrological conditions on steep slopes, rendering them susceptible to saturation (Mugagga et al., 2012). This may trigger debris flows during rainfall events. There is need to restore forest cover on the fragile steep slopes and restrain local communities from opening new areas for cultivation on critical slopes, particularly within the protected area. A study conducted by Odira et al., (2010) on the Impact of Land Use /Cover dynamics on Streamflow: A Case of Nzoia River Catchment, Kenya. The Nzoia system has its sources in the forested highlands (Mt. Elgon, Cherangani Hills, Nandi Hills and Kakamega forest).

Focusing on simulating streamflow changes because of the land use/cover status as of 1973, 1986 and 2000 supported by (Cuo, 2016). According to Cüceloğlu et al., (2021), the runoff response due to the observed land use/cover change was tested by keeping constant all input datasets in a SWAT model and varying the land use showed that with the expansion of the area under agriculture, the stream flow increases during the rainy seasons and reduce during the dry seasons, whereas when the area under forest cover is increased, the peak stream flow reduces. However, when the forest cover is reduced to almost zero there was an increased peak and mean stream flow in the basin (Odira et al., 2010). The annual rate of decrease from 1972 to 2004 in forest, wetland and marshy land were 91.22, 27.56 and 39.52 ha/year, respectively (Mishra, 2021)

Land cover change analysis has shown that the agricultural area has increased from about 39.6 to 64.3% between 1973 and 2001, while forest area has decreased from 12.3 to 7.0%. Results from the calibrated model showed that generally, runoff was highest from agricultural lands, followed by shrubland, grasslands, and forest. The study found that land cover changes would explain a variation in runoff of around 55-68% in the absence of climate change. In contrast, a 30- 41% variation in runoff was explained by climatic change alone, unaffected by changes in land cover. According to Githui et al., (2009), changes in land cover have had a more significant impact on runoff than climate change. The annual rate of increase from 1972 to 2004 in agricultural land and settlements was 181.96, 9.89 ha/year, respectively, (Behera et al., 2012).

Land degradation, irregular rainfall, soil moisture stress, the rejection of conventional methods for improving soil fertility, and the ineffectiveness of inorganic fertilizers have all worked together to reduce Lenche Dima's crop yields. Furthermore, there has been a reported decline in the number of crop varieties planted from nine to four, which has constrained the output possibilities, (Ali, 2009). A study conducted in Ethiopia examined the changes in land use and land cover, as well as the effects of Jatropha on soil fertility. The study found that throughout the specified years, there was an increase in agricultural land, bare ground, and built-up land cover. This rise came at the expense of bush and shrub land, as well as degraded bushy grass field. (Ayele, 2011). Additionally, it was demonstrated that farming operations provide the primary means of subsistence, but their lack of efficient control methods also makes them the primary cause of watershed degradation.

To address degradation in catchment areas, it is important to implement measures that involve active participation in planning and management. This should include improved coordination, the promotion of alternative livelihoods, and a thorough review of policies and regulations that may be ineffective (Bass & Mayers, 2013). It is also crucial to enforce existing legal and policy frameworks, adopt an ecosystem-based approach to catchment conservation, and establish a national coordinating body within the decentralized governance system of the country. (Roy et al., 2011)

2.2 Empirical Review

Empirical review is an approach to assessing the evidentiary value of a research area. It involves selecting a cross-section of studies for replication and evaluating their replicability. The goal assesses the extent of land use, land cover change in Koitobos river catchment of Trans Nzoia County Kenya which was to incorporate strength of evidence as researchers refine theories and plan new investigations in the research area. It allowed for integration of qualitative and quantitative approaches to assess and enable planning for environmental sustainability within the catchment. Land use and land cover (LULC) change is a global environmental concern that affects the human survival environment, food safety, and the Earth's water-land-carbon cycle. These theories are in line with the study undertaken especially on settlement and population increase determine the change and transitions in land use (Mubea & Menz, 2012).

A study on Evaluating change detection techniques for monitoring land-cover changes established that the area of soil cover decreased from 51.95 km2 in 1990 to 32.24 km2 in 2000, due to the urban growth from 0.68 km2 in 1990 to 9.50 km2 in 2000 and land reclamation (vegetation growth) from 0.59 km2 in 1990 to 11.48 km2 in 2000 (Afify, 2011). According to research on land use land cover change detection using remote sensing data and GIS tools, the Northwest district saw a comparatively large rise in both population and built-up areas. Buildings and roads ate away almost 10,000 hectares of farmland in Delhi over the course of 19 years, increasing the city's built-up area to 18%. Up to 1987, these farmlands were mainly located in Delhi's northwest and western parts. Urbanization also resulted in the loss of forest areas. During the study period, (Marques & Marques, 2020)recorded the loss of almost 11,000 hectares of forest area, including both open and deep forest. A study that utilized satellite-derived maps to examine watershed dynamics and land use/cover patterns from 1972, 1990, 1999, and 2005 found that residential/industrial development, settlement proximity, and other biophysical and socio-economic drivers had an impact on the watershed's land use/cover patterns, causing agricultural and settlement areas to expand linearly. In contrast, eucalyptus tree plantations, annual crops and bare land/open grassland cover increased at a rate of 2.8, 12.5 and 24.8 ha per year, respectively.

Correspondingly, bare land/open grassland increased by 344.5% at the expense of shrinking shrub grasslands and expanded into uninhabited areas, (Daniel, 2008).

The main reasons for the changes in land use and land cover can be attributed to the following: rising population pressure and all the problems that come with it, including a lack of land tenure security and inadequate infrastructure development, as well as unfavorable government policies (Ayalew et al., 2008). In the Blue Nile and A wash basins of Ethiopia, Kuhar Michael and Lenche Dima conducted a comparative study on land use and land cover change, drivers, and impact. They found that although there were sporadic variations in the amount of land changed, the overall rate of change over the entire analysis period (1972–2005) was found to be 0.8% per year, which led to a net increase in land use and land cover change (Oumer et al., 2020).

A study on livelihood activities and wetland conservation in the upper Nzoia river basin, western where results showed that population pressure and consequent intense and widespread land cultivation led to changes in the biophysical features such as land fragmentation, narrowed river channels depletion of vegetation cover and deterioration in water quantity, (Sakataka & Namisiko, 2014) The extension of agriculture around the world is being propelled by rising populations and the rising need for agricultural output. The loss of biodiversity, land degradation, and overexploitation of delicate ecosystems are all consequences of these expansions (Lal, 2001) set out to determine what variables in Kenya's Trans Nzoia County were responsible for land use/land cover changes (LULCCs) and the subsequent growth of farmland.

III. METHODOLOGY

3.1 Research Design

The choice of the research design was determined by the indicators within the specific objective of the study as stipulated in the table 3.1.

Table 1

Objective, Variables, and Research Design Adopted in the Study

Specific Objective	Indicators	Research Design
Assess the extent of land use, land cover change in Koitobos river catchment, Trans Nzoia County Kenya.	Forest land Agricultural land Settlement and Urbanization Water bodies	Google Earth Engine techniques and GIS & Remote sensing techniques through (USGS). Cross-sectional survey with questionnaires.

As indicated in table 1, the choice of these research design was justified by the fact that the study area had over the last 40 plus years, undergone land use transformation from dominant large-scale grain and dairy farming to medium to small-scale mixed farming. In the subsequent expansion and transformation of farming, watersheds had come under increasing cultivation pressure due to a rise in immigration of land–seekers and business, people from different ethnic, cultural, and economic backgrounds in Kenya. Besides the different approaches to land use and livelihood searches, it was evident that other socio-economic demographic variables appeared to have a strong bearing on the biophysical transformations witnessed in riparian ecosystems in recent years. This study targeted officers from government department, non-governmental organizations, traders, and service providers in category one. In the second category, the study targeted farmers (landowners), local community members, focus group discussion members. Government departments, government organizations, websites, and reports provided statistics about their population. The study used a combination of descriptive survey, cross-sectional, Google Earth Engine (GEE) and United States Geological Satellites (USGS) applications.

The survey design permitted assessment of deforestation and encroachment activities, Agricultural activities (farming practices), Settlement and Urbanization, Landslides, and mudslides, population growth in relation to land use land cover changes, variability in rainfall in relation to surface runoff and precipitation, human and natural activities, and environmental policies in place. The researcher employed both quantitative and qualitative approaches to data collection, analysis, and presentation. Historical design assisted in exploring, explaining, and understanding the past about the subject from data already available. The aim was to collect relevant information that provided baseline data upon which land use cover change, forestry, and agriculture would be determined for future development planning. The cross-sectional design was used to determine the extent of deforestation activities, agricultural activities (farming practices), settlement and urbanization together with other natural processes such as landslides and mudslides within the catchment for the period. Further, cross-sectional design was used to examine variations in rainfall, precipitation, human and natural activities within the catchment because of land use land cover changes.

3.2 Study Area

The study was undertaken in Trans Nzoia County within the upper Nzoia basin covering the river Koitobos catchment area in Kwanza Subcounty and stretching to partly Endebess Sub- County and along the Mt. Elgon forests and water tower. The Koitobos river catchment is located on Latitude: 0.8958° N and Longitude: 35.1163° E, in the highlands of Trans Nzoia County. With a target population of 203,821 residents in the sub county of Kwanza. River Koitobos catchment, and its river valley supports the population of approximately 203,821 (Statistics, 2019), residents for Kwanza sub-county, Trans-Nzoia, from which officials of non-governmental organizations, community-based organization (CBO) and Faith Based Organization (FBOs) in the region, and relevant state ministries were derived. This implied that the target population was 203,821; a sample of 384 was drawn from this figure to form sampling unit as per the (Chuan & Penyelidikan, 2006) in their research considered used the table for Determining Sample Size as generated by Krejcie and Morgan in there research. The area of study covered majorly the catchments within the Kwanza Sub-County of which its population largely depended on the Koitobos river water resource for domestic and farming activities.

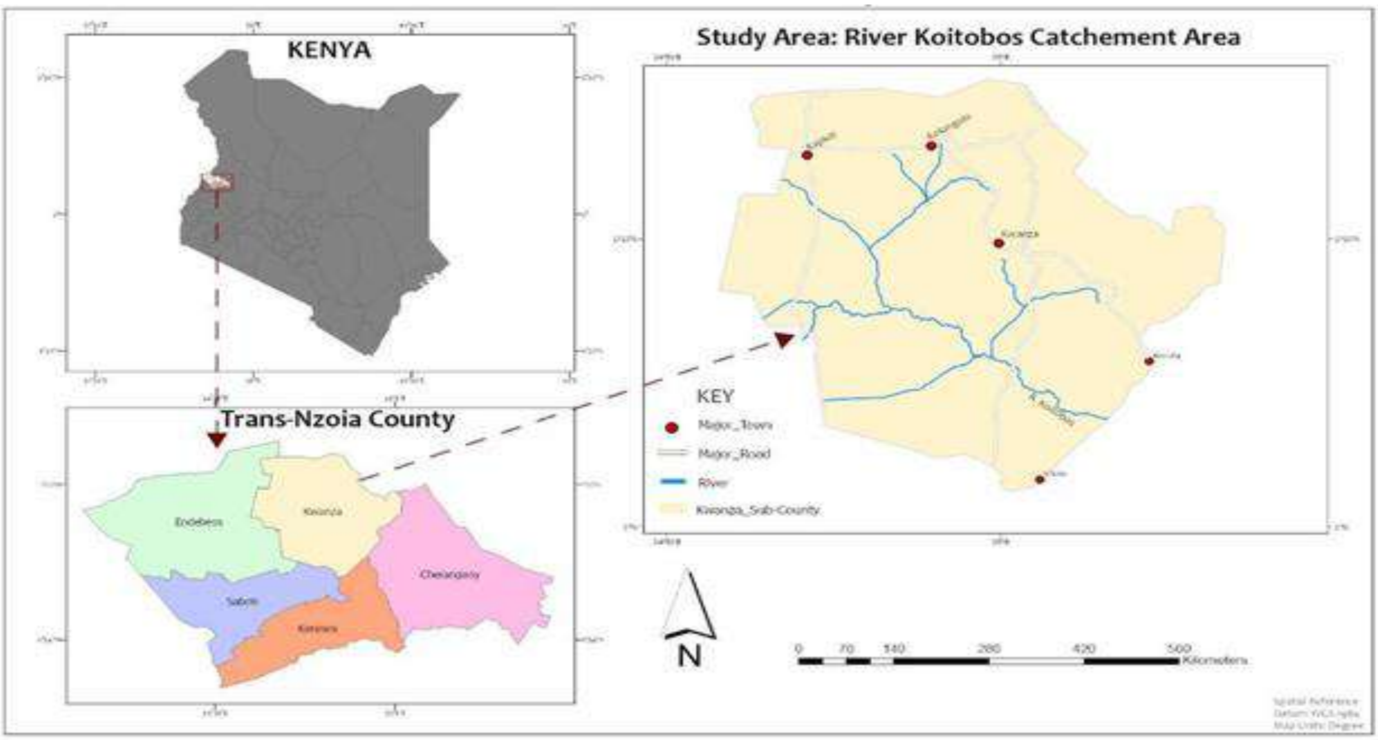

Figure 1
River Koitobos Catchment Area Located within Trans Nzoia County

3.3 Target Population

According to reports from the Ministry of Agriculture, Trans-Nzoia County, River Koitobos catchment, and its river valley supports the population of approximately 203,821 (Statistics, 2019) residents for Kwanza sub-county, Trans-Nzoia, from which officials of non-governmental organizations, community-based organizations (CBOs) and Faith Based Organization (FBOs) in the region, and relevant state ministries were derived. This implied that the target population was 203,821; where a sample was drawn to form sampling units. The area of study covered majorly the catchments within the Kwanza Sub-County of which its population largely depended on the Koitobos river water resource for domestic and farming activities.

3.4 Sample Size and Sampling Procedures

To make it simpler the method of determining the sample size for a finite population, the researcher used the (Krejcie & Morgan, 1970) Table for Determining Sample Size from a Given Population as indicated in Table 2.

Table 2
Table for Determining Sample Size from a Given Population

N	S	N	S	N	S	N	S	N	S
10	10	100	80	280	162	800	260	2800	338
15	14	110	86	290	165	850	265	3000	341
20	19	120	92	300	169	900	269	3500	346
25	24	130	97	320	175	950	274	4000	351
30	28	140	103	340	181	1000	278	4500	354
35	32	150	108	360	186	1100	285	5000	357
40	36	160	113	380	191	1200	291	6000	361
45	40	170	118	400	196	1300	297	7000	364
50	44	180	123	420	201	1400	302	8000	367
55	48	190	127	440	205	1500	306	9000	368
60	52	200	132	460	210	1600	310	10000	373
65	56	210	136	480	214	1700	313	15000	375
70	59	220	140	500	217	1800	317	20000	377
75	63	230	144	550	225	1900	320	30000	379
80	66	240	148	600	234	2000	322	40000	380
85	70	250	152	650	242	2200	327	50000	381
90	73	260	155	700	248	2400	331	75000	382
95	76	270	159	750	256	2600	335	**100000**	**384**

NOTE: "N" is the population size
"S" is the sample size.
Source: *Krejcie, & Morgan,* (1970)

There is no need of using the formula since the table of determining sample size has all the provisions you require to arrive at your sample size. Based on the target population as given in section 3.5, the target population for Koitobos river catchment of Kwanza Subcounty in Trans Nzoia County was 203,821 (Statistics, 2019) residents. Using the Krejcie & Morgan, (1970) Table for determining sample size, the desired sample size will be 384. While during the administration of the questionnaires the response was 312 which was used as the N sample in this study.

3.5 Sampling Procedures

The research conducted interviews with 21 key informants comprising of 3 experienced partners each representing land owners, small-scale, medium and large scale farmers; 7 Officers each representing a key department of government in the study area, namely Lands, Agriculture, Water, Health, Administration, Livestock, and Education; 6 Officers each representing key parastatal organization in the study area, namely KWS, NEMA, WRMA, KFS,KMD and CRS; 2 NGO/CBO Officials each representing World Vision and Vi-Agroforestry and 3 traders involved in the supply chain of Agro-inputs. This is summarized in Table 3 thus indicating population units, sampling method and sample size.

Table 3
Sampling Strategy of the Study Population

Study Population Units	Sampling Method	Sample Size
Key Informant Interviews (KII)	Stratified random with proportional allocation and purposive	21 Service Providers, Government Departments, NGOs and Dev. Partners, Traders (21 persons)
Landowners /Households and residents	Stratified random with proportional allocation	384 participants
FGD Members	Quota	3 FGDs with total 30 participants in different locations (Each FGD having 8-12 members) drawn from the residents and service providers.

The purposive selection of key informants aimed at drawing representation from business, the farming community, policy makers and institutions in the farming and environmental conservation fields within and outside the study area. The information to be gathered covered the key socio-economic parameters and the overall livelihood characteristics of the communities, as well as specific land use practices.

Proportionate stratified random sampling was used in selecting catchments and households. In addition, quota sampling was used in selecting participants in the individual watershed FGDs. Quota sampling was used in selecting vulnerable individuals in households to discuss community-wide vulnerability issues.

3.6 Data Collection Procedures

Primary data was collected through structured questionnaires, key informant interviews, focus group discussions, observation checklist, and community vulnerability assessments. While secondary data was collected through the review of literature from Libraries, on-line and off-line browsing of international journals and peer-reviewed articles.

3.7 Data Analysis Techniques

3.7.1 Primary Data

Quantitative data collected using structured questionnaires was analyzed using Statistical Package for Social Science, SPSS with Microsoft excel applications and the findings were presented in tables and charts. The findings were in descriptive statistics, which is usually in percentages and frequencies. Qualitative datasets collected using key informant interviews, focus group discussions and community vulnerability assessments were analyzed using thematic content analysis where findings were grouped into themes and sub-themes for easy analysis and understanding. After the qualitative data was analyzed, it was tabulated for simplicity, and understanding and presentation.

3.7.2 Secondary Data

Data collected from publications, reports, journals, books, and other secondary data sources was analyzed using Google Earth Engine (GEE) and remote sensing (RS) techniques which detects changes, maps trends, and quantifies the differences on the Earth's surface. GEE is widely applied in land use and land cover research and now available for commercial use and remains free for academic and research use.

The formula for calculating the AWEI is as follows:

$$AWEI = 4 * (GREEN - SWIR2) - (0.25 * NIR + 2.75 * SWIR1) \quad \text{……e.g. (1)}$$

Where;

AWEI = Automatic Water Extraction Index

SWIR = Shortwave Infrared

NIR = Near-Infrared

IV. FINDINGS & DISCUSSIONS

4.1 Deforestation Activities within the Period of 2001 – 2021

From the findings of the study, there has been increasing deforestation practices in the study area that have been attributed to the increasing population demanding food and need to increase the agricultural land to meet the food supply needs. In addition, the decrease in forest cover can be attributed to the fragmentation of farming parcels and encroachment into the existing protected areas of vegetation and extending into riparian areas for farming activities. Table 1 clearly stipulates the acreage of deforestation in Koitobos river catchment generated using Google Earth Engine techniques for the period 2001 to 2021.

Table 4

Deforestation Activities in Koitobos River Catchment

Year	Acreage (Ha)
2001	7.614
2002	4.827
2003	28.648
2004	5.761
2005	6.793
2006	3.031
2007	14.5
2008	19.129
2009	3.665
2010	11.888
2011	4.469
2012	19.189
2013	16.804
2014	9.312
2015	7.24
2016	81.542
2017	137.198
2018	25.92
2019	63.146
2020	72.808
2021	41.6

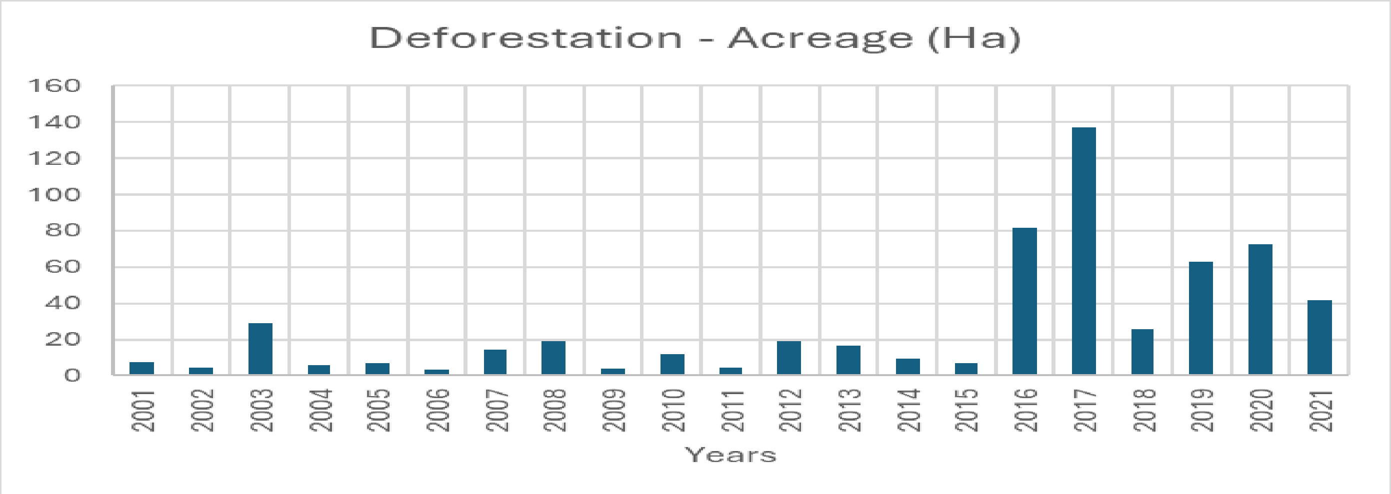

Figure 2

A Bar Graph Showing Deforestation Cover (Ha) Over Time for the Period 2001 to 2021 in the Koitobos River Catchment

Land use change from forestry to agriculture is increasingly from year to year within the Koitobos river catchment to catch up with the increasing demands of the residents in the area. The year 2016 and 2017 had great significance of deforestation activities in the Koitobos river catchment in the transition period of 2001 – 2021 where the activity scaled to about 138 hectares (Ha) of forested land which contributed to the highest percentage of land degradation.

4.2 Land Use Cover Changes Realized by the Community of the Koitobos River Catchment

The results depicted by the land productivity dynamics are as indicated on Figure 2, while the acreage is as illustrated in Table 2. Land use/land cover change has increasingly affected the land productivity dynamics within the Koitobos river catchment and thus contributing to environmental degradation.

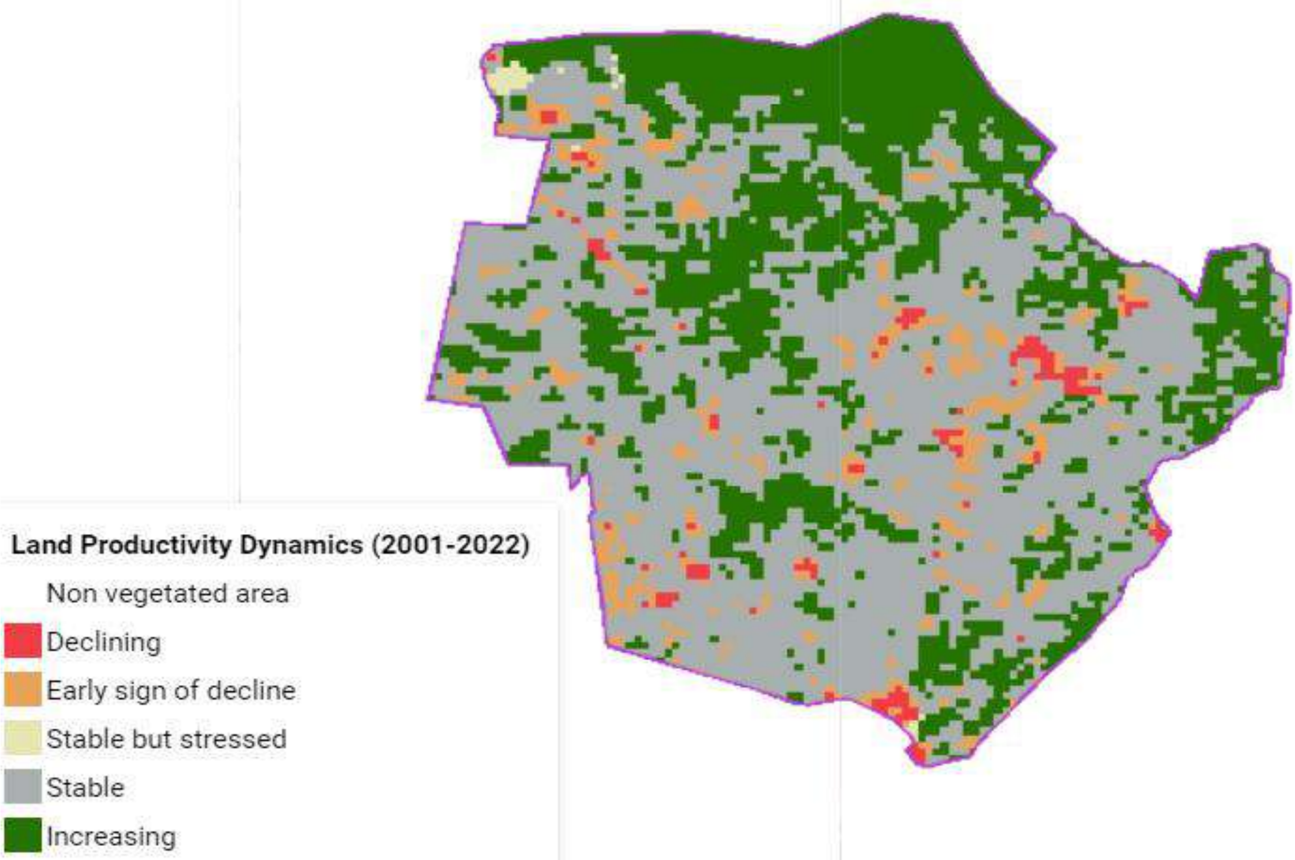

Figure 3
Land Use Cover Changes Realized by the Community in the Koitobos River Catchment

Table 5
Land Productivity Dynamics within the Koitobos River Catchment

Land Productivity Dynamics (LPD)	**Area (Ha)**	**%age**
Declining	893.272	1.9
Early sign of decline	2,892.23	6.2
Stable but stressed	176.833	0.4
Stable	27,317.98	58.8
Increasing	15,198.06	32.7
TOTAL	**46,478.375**	**100.0**

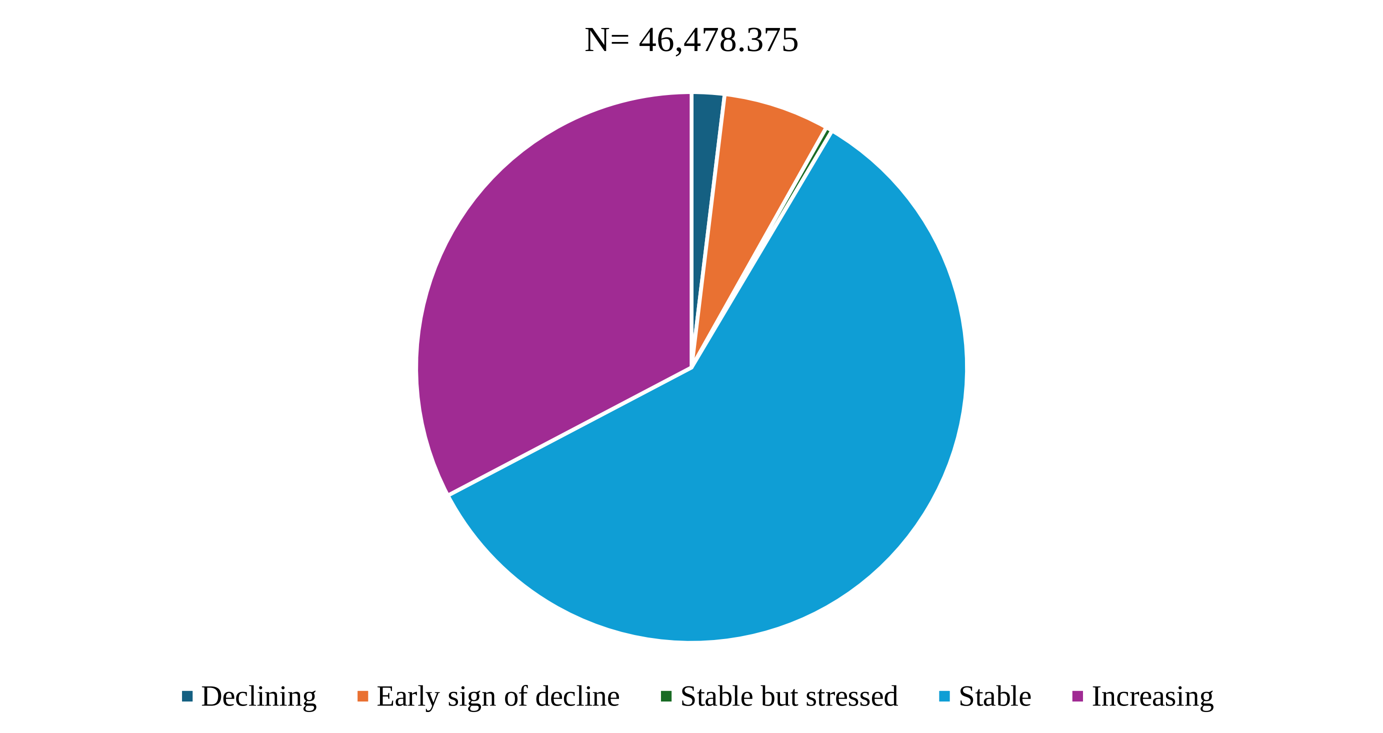

Figure 4
Land Productivity Dynamics in the Koitobos River Catchment

From Figure 4, it is depicted that, there has been increasing situation of land productivity dynamics from land use practices in the area that is attributed to the increased pressure on the limited land resources that trigger creation of diverse land cover changes. Stable variations are depicted from the area at 58.8%, due to the stabilized population growth with increasing variations due to the increasing degradation at 32.7% within the catchment. This negatively affects the availability of surface water in the Koitobos river catchment which is dependent on this resource for domestic and farming activities needed for sustaining the growing population.

Table 6
Land Cover Transitions in 2021, in Koitobos River Catchment

LULC Type	Value (Area- Ha)	%age
Forest	6,798.69	14.6
Mangrove	0	
Shrubland	6,058.93	13
Grassland	5,453.61	11.7
Cropland	27,510.06	59.2
Artificial	603.531	1.3
Wetland, Water body and Other land	55.570	0.2
TOTAL	**46,480.39**	**100.0**

From Table 6, cropland covers an area of 27,510.06 which represents 59.2% of the total catchment area. On the other hand, Forest covers 14.6%, while Shrub land and Grassland covers 13% and 11.7% of the total area of the study area respectively. Fragmentation of farming parcels and encroachment into the existing protected areas such as forests, shrub lands and grass lands have influenced the level of acreage of the selected LULC types in the study area. It is concluded that land use/land cover change from forestry to agriculture increased in acreage from year to year within the Koitobos river catchment due to the need to meet the increasing demands of the residents in the study area.

These findings of this study corroborate with other past studies. For instance, Ayele et al., (2012), in their studies in the Lake Tana basin of Ethiopia, realized that in the 32-year period that was considered (between 1972 and 2004), shrub-grassland and riverine trees cover had decreased at a rate of 21.5 Ha and 16.3 Ha per year respectively, while riverine trees suffered the greatest devastation from riparian encroachment and by the year 2004, the trees had been reduced to only 16% of their cover in 1972.

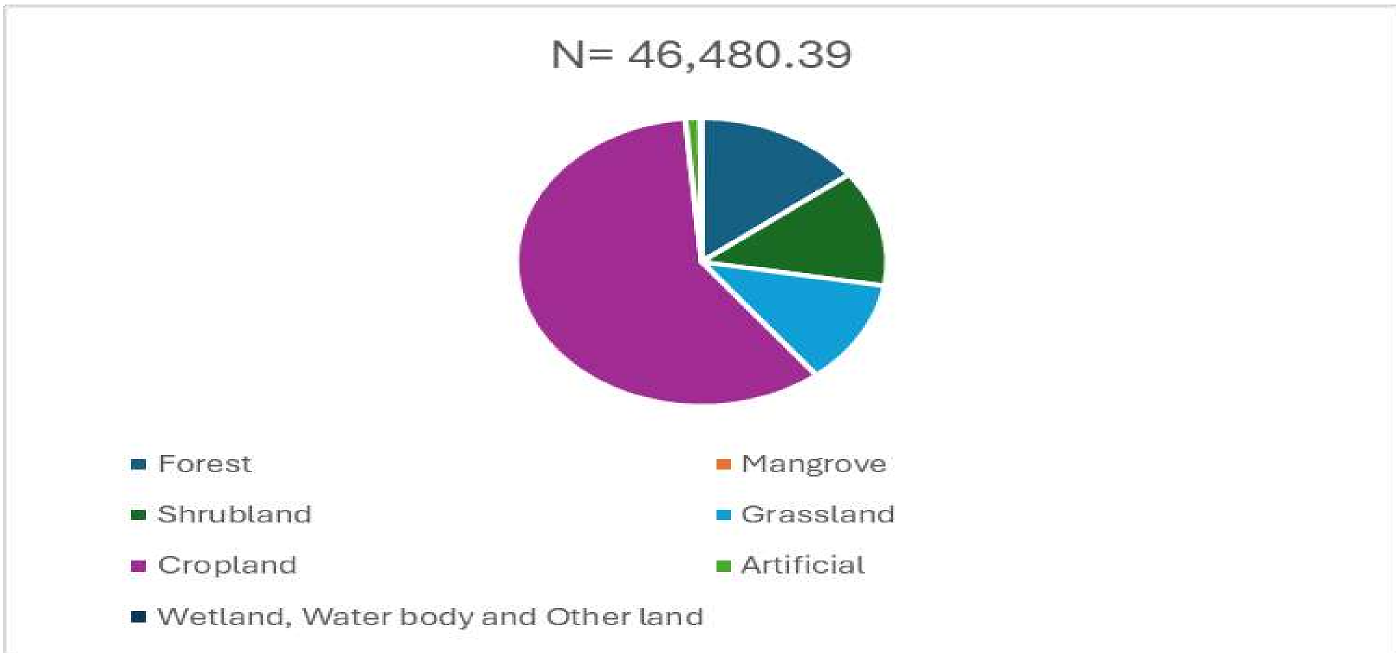

Figure 5
Land Cover in 2021 within the Koitobos River Catchment

A visual inspection of Figure 5 depicts that cropland has the largest cover. This explains why there has been increasing deforestation practices in the area that can be attributed to the increasing population demand for food and hence the need to increase the cropland to meet the food supply needs.

The established five distinct land use/land cover classifications encompassed agriculture, barren land, forest, developed/built-up areas, and water bodies.

4.3 Land Use Land Cover Change of Koitobos River Catchment in Hectare

The table 7 indicates the land use land cover areas in hectares and percentages compared to the total coverage of the Koitobos river Catchment (Table 7).

Table 7
Land Use Cover of Koitobos River Catchment

LULC	1995		2009		2022	
Class / Year	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**
Agriculture	26853	58	32438	70	36118	77.68
Bare land	14915	32	8093	17	6175	13.28
Developed/ Built up	154	0	514	1	459	0.99
Forest	2242	5	1647	4	222	0.48
Water	2332	5	3803	8	3521	7.57
TOTAL	**46495**	**100**	**46495**	**100**	**46495**	**100**

The findings of land use, land cover change for the years 1995, 2009 and 2022, within the study area showed that agricultural land covered majority of the catchment with an area of 26,853 Ha (equivalent to 58%), 32,438 Ha (equivalent to 70%), and 36,118Ha (equivalent to 77.68%) respectively when transitioning through the years of the entire catchment , thus showing a drastic increased changes in area on the same. This was followed by bare land area which covered an area of 14,915 Ha (equivalent to 32%), 8,093 Ha, (equivalent to 17%) and 6175 Ha (equivalent to 13.28%) of the entire catchment area as shown in the table which drastically decreases transitionally as the agricultural land increases due to the pressure exerted on the resource.

The forest land had shown a drastic decreasing trend through the transitional period from 2242 Ha (5%) to 1647 Ha (equivalent to 4%) and then 222 Ha (equivalent to 0.48%), and this due to increasing demand for more space by the growing population which increasingly results to deforestation activities of unplanned cutting down of trees within the catchment. Water resources within the Koitobos catchment showing an increasing trend from the year, 1995, 2009, and 2022 as follows, 2332 Ha (equivalent to 5%), 3803 Ha (equivalent to 8%), and 3521 Ha (equivalent to 7.6%) and this resulted from the digging of new water pans, dams and protected water points and streams contributing to increased aspect. Also reduced abstraction from the river for irrigation purposes contributing to some amount of area covered within the catchment by water resources.

Agricultural land in the years 1995, 2009, and 2022 spread all over the Catchment separated by patches of bare lands, water, and forests. Showing that in this transitioning period of 1995, 2009 and 2022 years, the major land use land cover changes was Agriculture land covering 58%, 70% and 77.68% of the entire area coverage within the Koitobos River catchment. This was due to the increasing demand for food supply of the ever-growing population as depicted by the KNBS reports in every transition having been corroborated by (Dey et al., 2021)in their study on Athi River, detecting and predicting land use land, cover changes in the upper river valley using Cellular Automat- Markov Model, who stated that in the future agricultural expansion, and related development will account for most of the land use, land cover changes.

4.3.1 Land Use Land Cover Map for Year 1995

Agricultural land in the year 1995 covered an area of 26,853 Hectares (Ha), which was 58% of the entire area of Koitobos river catchment. Most of the land was covered by agriculture, followed by bare land area which covered an area of 14,915 Hectares (Ha), 32% of the entire Catchment. The remaining land of the Catchment area was developed/ built up, Forest and water in percentages of 0, 5, 5 respectively. Agricultural land in the year 1995 spread all over the catchment separated by patches of forests and bare lands. Showing that in this year, the major land use land cover changes was Agriculture land covering 58% of the entire area coverage of the catchment as indicated in figure 4.5.

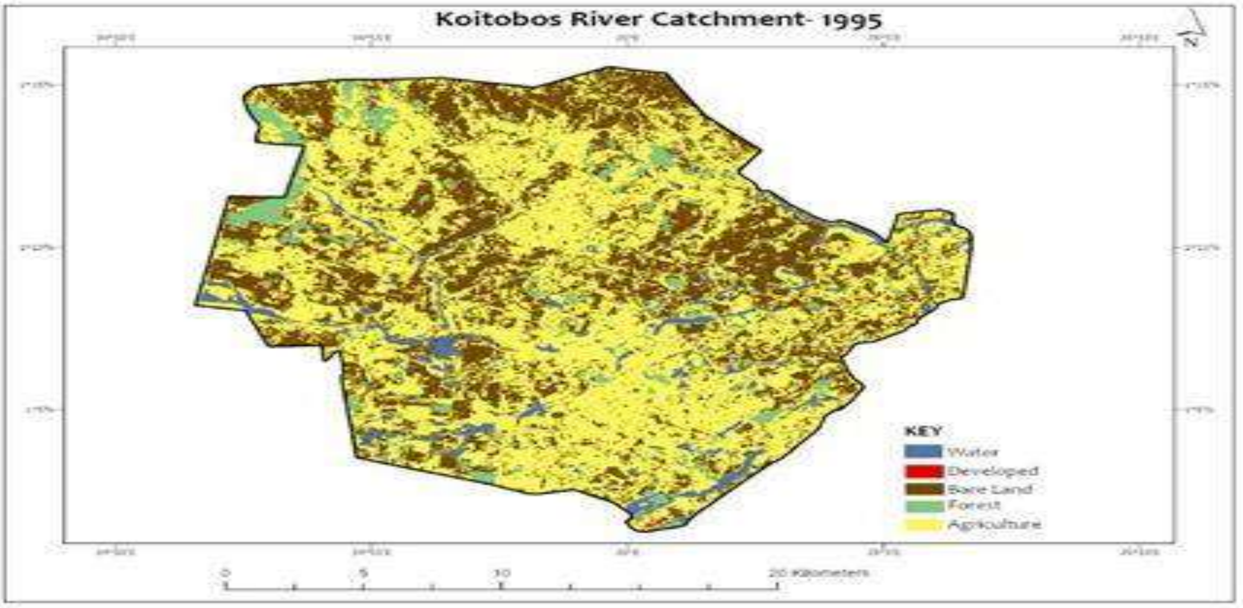

Figure 6
LULC Map for the Year 1995 within Koitobos River Catchment

4.3.2 Land Use Land Cover Map for Year 2009

Agricultural land in the year 2009 covered a majority of the Catchment with an area of 32,438 Ha, which was 70% of the entire Catchment followed by bare land area which covered an area of 8,093 Hectares (Ha), 17% of the entire Catchment area as shown in the table. The remaining land of the entire Catchment area was covered in Developed/ Built up, Forest and water in percentages of 1, 4, 8 respectively. Agricultural land in the year 2009 spread all over the Catchment separated by patches of bare lands. This indicates that in this year, the major land use land cover changes were Agriculture land covering 70% of the entire area coverage of the catchment. This was due to the increasing demand for food supply of the ever-growing population as depicted by the KNBS reports in every transition as indicated in figure 7.

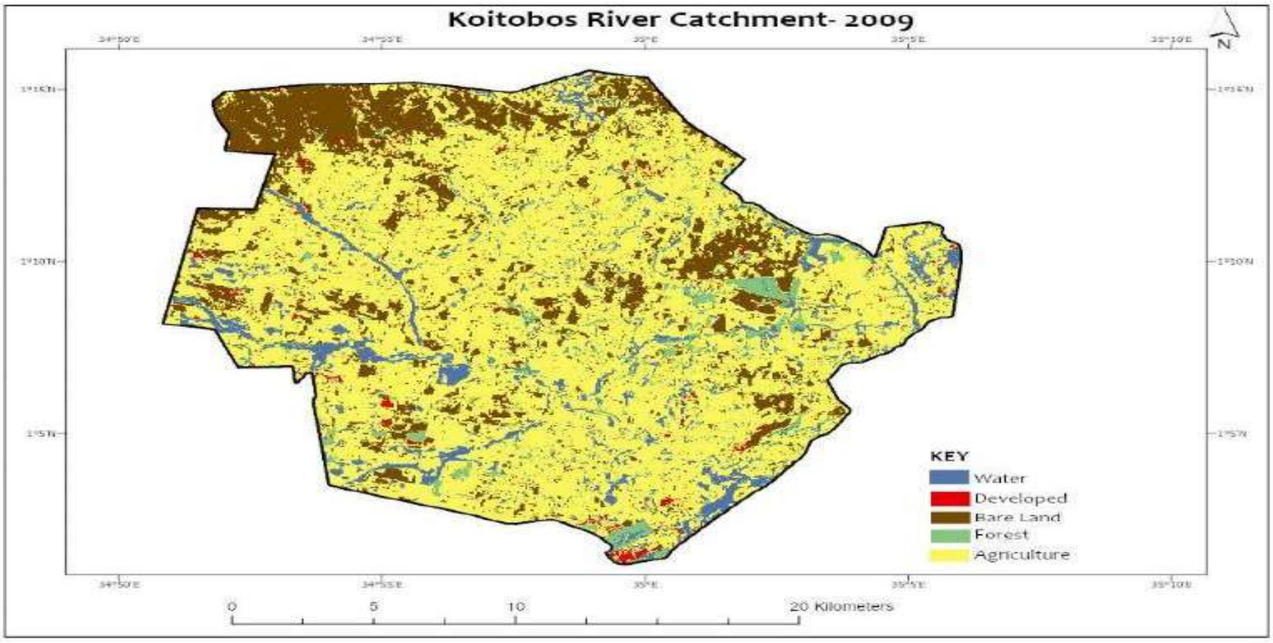

Figure 7
Land Use Land Cover Map for Year 2009

4.3.3 Land Use Land Cover Map for the Year 2022

Agricultural land in the year 2022 covered an area of 36,118 Hectares (Ha), which translates to 77.68% of the entire Catchment area. Bare land rated second in area size of 6,175 Hectares (Ha), with a percentage of 13.28 while the remainder of the Catchment area was covered in Developed/ Buil up, Forest and water in percentages of 0.99, 0.48 and 7.57 respectively. The built-up areas had intensively shifted everywhere in the Catchment as compared to 27 years earlier which were only concentrated on the urban center. The forested area and bare land had reduced immensely as evidenced by patches that spread all over unlike the previous year of analysis. Showing that in this year, the major land use land cover change was Agriculture land covering 77.68% of the entire area coverage of the catchment as indicated in figure 8.

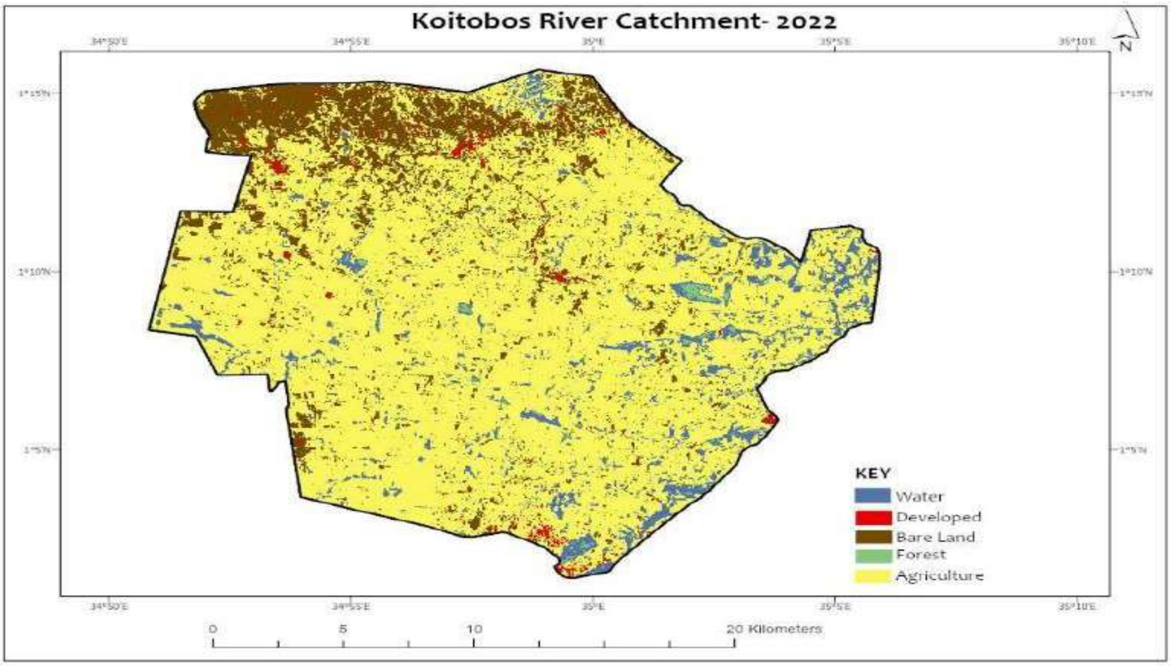

Figure 8
Land Use Land Cover Map for Year 2022

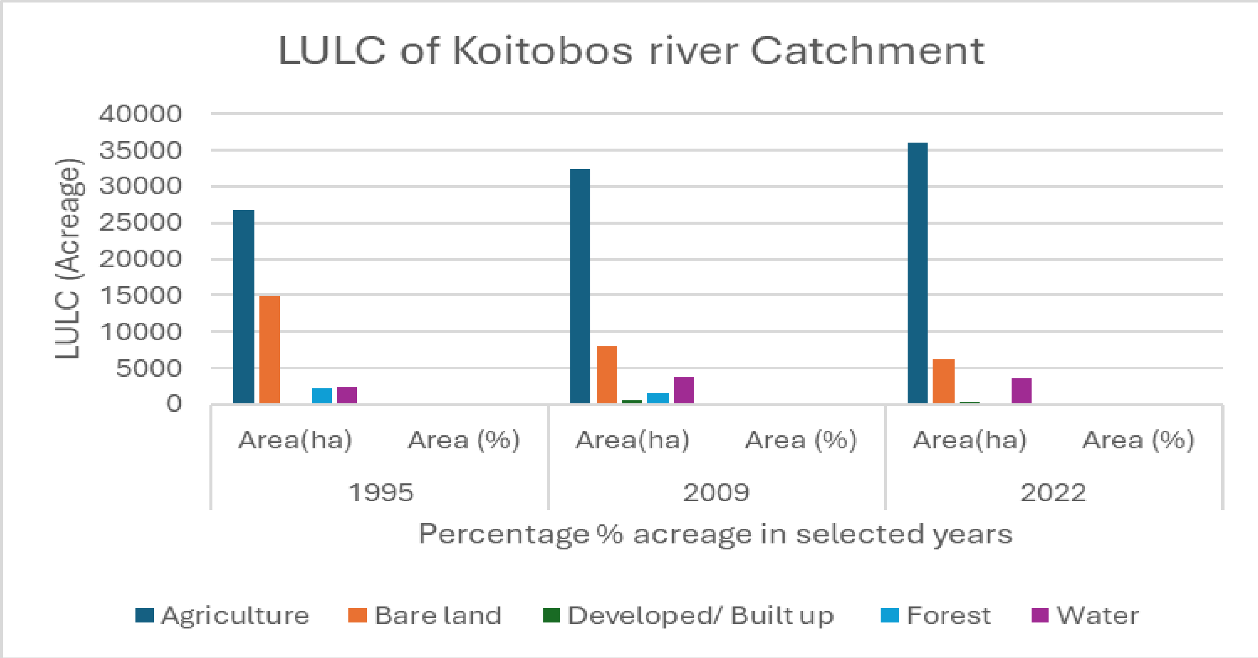

Figure 9
Koitobos River Catchment Acreage with Reference to LULC

4.4 Extent of Land Use, Land Cover Changes in Koitobos River Catchment

It was noted that while arable land had reduced, land prices had increased and therefore these had led to a decrease in on farm yields. Generally, transport was a factor that was difficult to access and access to extension support was very low. The study revealed that vegetation cover had reduced with the ratio of deforestation and afforestation not being directly proportional. The expansion of the urban built up surfaces led to loss of fertile farmland, and this was corroborated by the fact that already Koitobos river catchment is exhibiting expansion into the riparian areas where irrigated agriculture is the main economic activity. The fragmentation of the agricultural land parcels currently taking place is a clear indication that it is no longer viable. Poor governance and weak frameworks for environmental regulation as well as implementation coupled with rapid population growth caused the deterioration of environmental quality within the Koitobos river catchment and its environs. The negative impact on environment was attributed to laxity among the locals in adhering to the government laws and regulations managing land use. Unsustainable and improper land use and land cover changes are the major causes of land degradation.

Some of these practices in the catchment included overgrazing of livestock, excessive clearing of forest or vegetation and other land use/land cover-based activities. It was realized that projections on population increase exerted pressure on land change and land cover thus influencing catchment conservation, due to land sub-division which reflects to be changing tremendously in the study area depicting increased pressure on the land resources.

It was also noted that increased unsustainable human activities will impact on land use/ land cover change in the river catchment and the climatic changes will influence food security, which will in turn is a determining factor of land use/land cover change. Also, the study guided that the growth of towns and urban centers within Koitobos River catchment will influence the vegetation cover and human activities undertaken in the area. Findings in this study show significant land use and land cover changes that have occurred in the Koitobos River catchment over the past 30 years.

Forestland and shrubland have declined, while cultivated land and artificial surfaces having increased in the area, and deforestation appears to be more pronounced within the catchment of the Koitobos River. Severe siltation downstream in the Koitobos river, appears to be strongly linked to increased soil erosion because of land use and land cover change. Notable drivers for LUCC include rapid population growth and GDP, macroeconomic activities occurring especially in the western part of the river such as manufacturing industries, and poor national policies that have failed to effectively enforce ban of uncontrolled harvesting of forest resources. To solve these problems, there is a need to review and amend weak policies that encourage noncompliance to regulations of managing forests. For example, all policies that may encourage or result in soil erosion such as riverbank cultivation must be amended. Powers should be invested in local authorities to take part in protecting the environment and/or in planting trees, and the government should be able to provide seedlings for the operation.

Deliberate programs should be instituted by the government to curb further effects of climate variability such as droughts and floods. Such programs may include good agricultural practices that conserve soil and protect it from water erosion, discourage riverbank cultivation, intensify afforestation programs, and ban the burning of charcoal.

Finally, the study findings indicated that the main causes of land use land cover changes in this basin included farming practices, population growth, infrastructural developments, climate change and land tenure systems. Therefore, a need to design sustainable conservation measures and policy strategies to preserve the water resources within the area. This has been supported by (Cheruto et al., 2016) in their studies in Moiben and Chepkaitit rivers' watershed which revealed from the analysis that the region has been subjected to a gradual process of conversion to other LULC due to high population pressure. The period 1980 – 2020 indicated a significant change in LULC, where while the crop land was increasing, the bush land, forest and wetlands were reducing. This was an indication that deforestation was being carried out in the region to create room for cultivation. Further, the wetlands also had been reclaimed to create room for agriculture, then meaning that the population had increased therefore, there being need to produce more food, and this creates pressure which drives LULC changes.

V. CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

From the study findings, three main conclusions were made as follows: - Firstly, the study concluded that an integrated watershed management approaches must be employed where all key and relevant stakeholders within the catchment are broad on board to land use management is well executed for sustainable periods.

Finally, the study concluded that with population increase exerting pressure on land use/land cover, increased prevalence of environmental impacts will be experienced due to land sub-division which predicts high gravity on the land resources. The study therefore concluded that establishment of sustainable soil water management measures together with adoption of sustainable land management practices will continually heal the land and conserve biodiversity within Koitobos river catchment.

5.2 Recommendations

The recommendations were generated based on negative findings from the concluded study with the aim of soliciting for viable interventions. The study recommends that: the impact of LULC changes to the river discharge is not impressive and thus, the study recommends that deforestation should be controlled by all. The locals, the environmentalists and the forest department should all take their initiatives. The laws that govern forest resource should be re-visited and thorough routine checks be done. Forest management authorities should normalize disciplinary measures through penalties for the policy breakers and the authorities should ensure that reforestation be done in the government forest lands that have been degraded. The landowners living in the catchment and riparian areas of Koitobos river should be encouraged to plant more agroforestry trees species in their farms as good protectors of the soil.

Firstly, there is need for establishment of sustainable soil and water management measures to uphold biodiversity conservation. Secondly, restoration of forest cover and restraining the local communities from opening new areas for cultivation on critical slopes, particularly within the protected areas is critical. And finally, recommended that all the proposed major developments in the Koitobos catchment which are likely to have environmental implications be subjected to Environmental Impact Assessment (EIA), in accordance with the provisions of Environmental Impact Assessment regulations of 2003. This proposal should be enforced by National Environment Management Authority (NEMA) in conjunction with the local and county Authority.

Protection of the fragile ecologies like the riparian vegetation and forests covers against encroachment by other human caused activities to be enforced by the laid down government policies. The land use suitability analysis is also imperative in protecting human life and the property. Loss of life and property may arise due to disaster as occasioned by poor location of land uses such as the residential developments along the riparian reserves which are prone to occasional flooding disaster.

The study recommended that sustainable land Management practices should be adopted to mitigate the exceptional adverse climate impacts that increasingly threaten the resilience of communities, Agriculture, food, and nutritional security within the catchment.

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