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THE TEMPORAL AND SPATIAL LAND USE AND LAND COVER CHANGES WITHIN KOITOBOS RIVER CATCHMENT IN TRANS NZOIA COUNTY, KENYA

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ABSTRACT

Universally, countries are facing pressure to meet the livelihood needs of their fast-increasing populations. This often leads to overuse of natural resources and consequent encroachment on fragile ecosystems such as river catchments and riparian areas especially in developing countries. The overall objective of this study was to assess the influence of land use, land cover changes on discharges within Koitobos River catchment between the period 1992 to 2022. Specifically, the study assessed the extent of land use/land cover changes within river catchment, evaluated the variations in water discharge volumes in Koitobos River, and predicted Land use Land cover change for the future. The Land use/land cover data was based on Landsat images within the period of study. The research design used was descriptive, Google Earth Engine (GEE) applications, United States Geological Satellites (USGS) application. A sample size of 384 people drawn from a target population of 203,821 residents were involved in the study. From the findings of Land Use, Land Cover Change in the years, 1995, 2009 and 2022, within the Koitobos River catchment showed that Agricultural Land, covered a majority of the Catchment with an area of 26,853Ha, (58%), 32,438 Ha (70%), and 36,118Ha (77.68%) respectively when transitioning through the years of the entire Catchment thus showing drastic increased changes in area, followed by bare land area which covered an area of 14,915 Ha (32%), 8,093 Ha, (17%) and 6175 Ha (13.28%) of the entire Catchment area extremely decreases transitionally as the Agricultural land increases due to the pressure exerted on the resource. The Forest Land showed drastic decreasing trend through the transitional period from 2242 Ha (5%) to 1647 Ha (4%) and then 222 Ha (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. 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 is due to the increasing demand for food supply of the ever-growing population as depicted by the KNBS reports in every transition. The study found out that increase in population resulted in an increased demand for food production in an environment where arable land couldn't be expanded therefore concluded that environmental policies and laws needed to be adopted in Koitobos river catchment. The study therefore recommended the adoption of sustainable land use management practices that continually heal the land and conserve biodiversity. Restoration of forest cover and restraining the local communities from opening new areas for cultivation on critical slopes, particularly within the protected area which is critical in protecting and conserving biodiversity within Koitobos river catchment.

Keywords:

Land Use, land cover changes, catchment area, Biodiversity, restoration.

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INTRODUCTION

This study provides a comprehensive background to research on the influence of Land Use Land Cover Changes within Koitobos River catchment, Trans-Nzoia County, Kenya. A full statement of the problem is given to point out the core purpose of the research. The main objective of the study was to evaluate the influence of Land Use Land Cover Changes on the Koitobos River catchment, Trans-Nzoia County, Kenya.

The most significant factors affecting surface runoff were changes in forests, agriculture activities, and built-up areas. A study on hydrological simulation by Liao (2018) on Wenyu River basin indicated that uncontrolled logging makes forest vegetation from a hydrological point of view unstable. In a previous study, logging action could influence the impact of the 100-year return period rain. Land use evaluation was needed within a certain period to determine trends in natural change that can be used for mitigation needs in the future. In addition to land use analysis, Guan, (2016), studies on runoff response to rainfall patterns, found out that it was also necessary to develop and implement a hydrological model of land use land cover changes to understand effects of runoff. There was a long history of research that had been carried out on automatic generation of river networks from digital elevation models (DEM). In assessing the Impact of Urbanization on Direct Runoff in Shenyang, China (2018), used an Improved Composite Method for extracting river channel networks using flow direction to calculate upstream contribution areas for each square grid. Through the model, they were able to define channels that simulated the hydrological patterns that affects land use land cover change.

Kapute (2019) assessed Land use and land cover changes over a 26-year period for the middle Shire River catchment in Malawi, southern Africa, using geographic information systems (GIS) and remote sensing techniques and observed that there was a high rate of deforestation averaging 4.3% per annum. Rapid population growth and increase in gross domestic product (GDP) were identified as the major drivers of deforestation and forest degradation due to clearing of vast fields for agriculture, land expansion for urban settlement, and cutting down of trees for wood fuel energy. The deforestation in the middle Shire River catchment was attributed to increased soil loss through erosion causing huge accumulation of sediments downstream that consequently, caused serious problems on land use land cover. Frequent droughts and floods experienced in the catchment because of poor land use drastically affected crop production forcing people into cutting down of trees for charcoal as a livelihood strategy. This implies that combined techniques such as GIS, remote sensing, and socioeconomic factors used in this study could be applied in other places where similar challenges do occur.

Based on studies by Kogo (2020), vegetation plays an important role in protecting soil from erosion, Consequently, accelerated soil erosion could lead to watershed degradation whereby there was loss in litter production, organic matter accumulation, and root growth. Borrelli (2020), was of the opinion that, 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.

Land use changes on the slopes of Mount Elgon on the side of Uganda indicated increased forest cover destruction because of agricultural encroachment. The vulnerability to land sliding of steep slopes with a northerly orientation, deforestation and cultivation of steep slopes lower the threshold of slope stability, as they alter soil hydrological conditions within the slope elements by way of enhancing saturation, hence triggering debris flows (Nakileza., 2017).

The Analysis of efforts and underlying causes of forest cover change in the various forest types of Kenya, done by Ministry of Forestry and Wildlife (2013), 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 reflects the cumulative effects of human activities both on the riparian and in the catchment areas. Hua (2017), Camara, (2019) and Achieng (2019), corroborates the finding by confirming that this phenomenon had been reported in several studies conducted to investigate the influence of land use and water quality in rivers in the region. Zaimes (2019) were of the view that, turbidity increase downstream mainly originates from agricultural areas and erosion from unpaved roads. Previous studies on rivers have also indicated that the water quality can deteriorate because of the intensification of agricultural activities and clearing of

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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.

A study on evaluating the impacts of land use changes on hydrological responses in the Koitobos river catchment revealed that over the past 150 years the area has experienced substantial land use changes from pre-settlement conditions. The study focused on some of these changes within the region and realized that massive deforestation, loss of wetlands and rangelands at the expense of agricultural production and urbanization. According to Guzha (2018), several land surface characteristics and processes were greatly affected by land use change, including leaf area, roughness, albedo, soil moisture, energy, and water vapor exchange rates. Land use changes such as urbanization, deforestation, and reforestation also continue to affect groundwater-surface water interactions including percolation or recharge, groundwater contributions to streams, and soil moisture as well as water availability influencing ecosystem services.

Studies by Musau (2015) on land use on the slopes of Mt Elgon revealed that land use and land cover was characterized by conflict between conservation measures and subsistence farming. Frequent landslides and floods initiated by high rainfall and land degradation in the area have claimed lives and destroyed property in the recent past. The area was endowed with a rich biodiversity, which influences lives and livelihoods of thousands of people through provision of 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 KFS and 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 continue 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".

OBJECTIVES

The overall objective of the study was to assess the influence of land use, land cover changes within Koitobos River catchment. Specifically, determine the extent of land use, land cover changes within Koitobos River catchment of Koitobos river due to land use, land cover changes and evaluate Land use and land cover change for the future within Koitobos River catchment.

METHODOLOGY

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.

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° 53' 45" N and Longitude: 35° 6' 59" E, at Lat/Long (dec): 0.89603,35.11639 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 (KNBS, 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

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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 Krejcie & Morgan (1970), Table for Determining Sample Size. The area of study covers majorly the catchments within the Kwanza Sub-County of which its population largely depend on the Koitobos river water resource for domestic and farming activities.

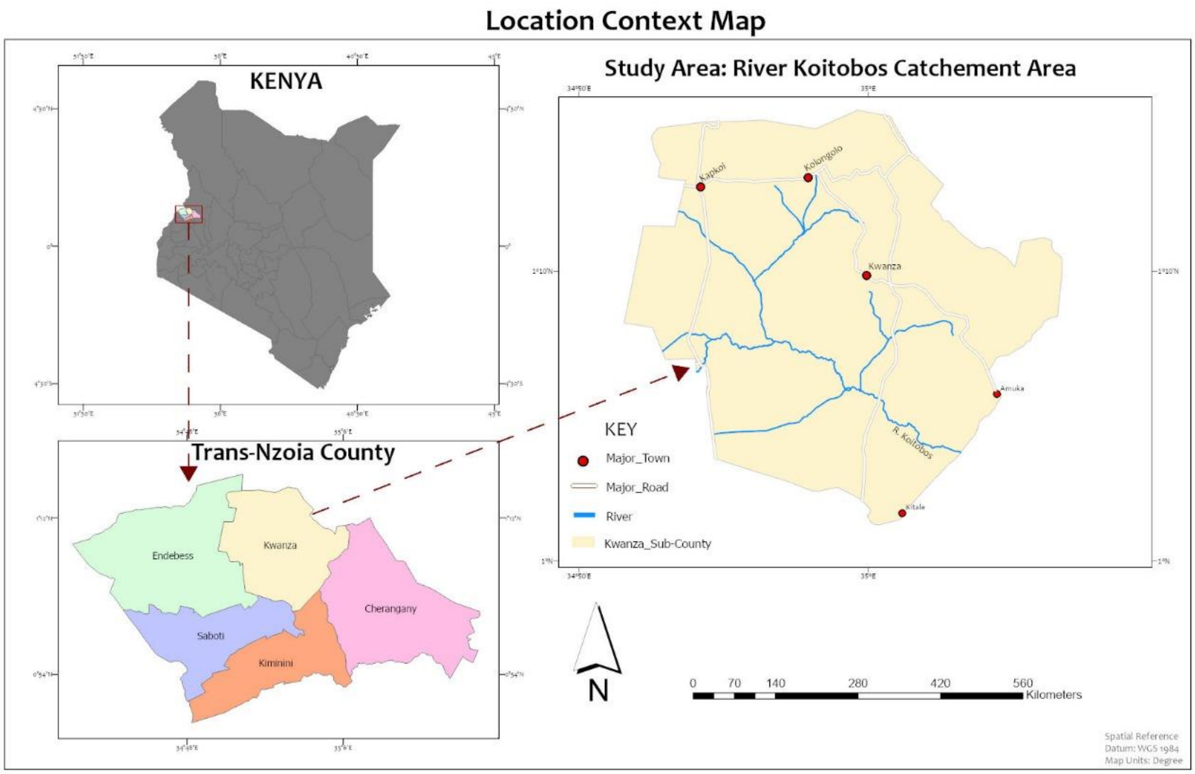

Figure 1 Location of the study area in the Koitobos river catchment

Table 1: Objectives, variables, and research design adopted in the study.

Specific Objective	Indicators	Research Design
Determine the extent of land use, land cover changes within Koitobos River catchment in Trans Nzoia County Kenya	• Deforestation activities • Agricultural activities (farming practices) • Settlement and Urbanization • Landslides and mudslides	Cross-sectional survey, Google Earth Engine (GEE) Application, USGS -United States Geological Satellites'.

RESULTS AND DISCUSSIONS

The table shows the band combinations that were utilized in the analysis of the land use land cover classes identified by the study.

Land use land cover change of Koitobos river catchment in hectare

The table below shows the land use land cover areas in hectares and percentages compared to the total coverage of the Koitobos river Catchment **(Table 2).**

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Land Use Land 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

From the findings of Land Use, Land Cover Change in the years, 1995, 2009 and 2022, within the Koitobos River catchment showed that Agricultural Land, covered a majority of the Catchment with an area of 26,853Ha, (58%), 32,438 Ha (70%), and 36,118Ha (77.68%) respectively when transitioning through the years of the entire Catchment thus showing a drastic increased changes in area on the same, followed by bare land area which covered an area of 14,915 Ha (32%), 8,093 Ha, (17%) and 6175 Ha (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 (4%) and then 222 Ha (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 (5%), 3803 Ha (8%), and 3521 Ha (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 Katana, (2013) 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.

The below map shows the land use land cover map for the year 2009.

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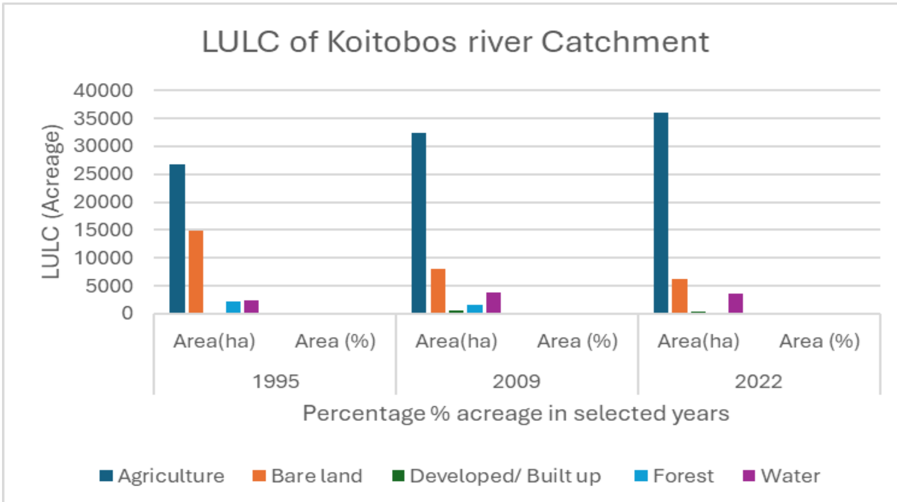

Figure 2- Showing LULC of Koitobos River Catchment

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.
The figure below shows the land use land cover map for the year 1995.

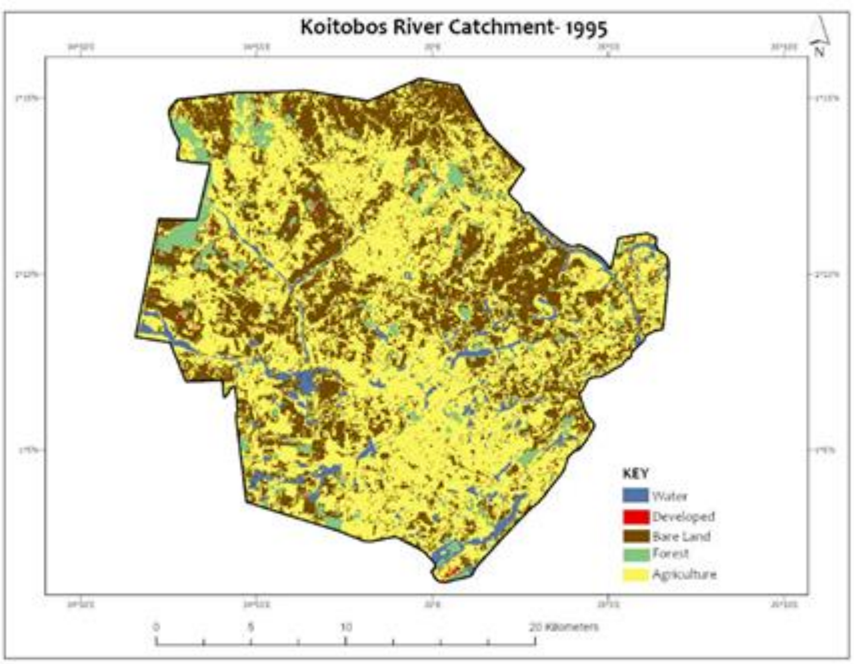

Figure 3 – LULC map for the year 1995 within Koitobos River catchment

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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. Showing that in this year, the major land use land cover changes was 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.

The below map shows the land use land cover map for the year 2009.

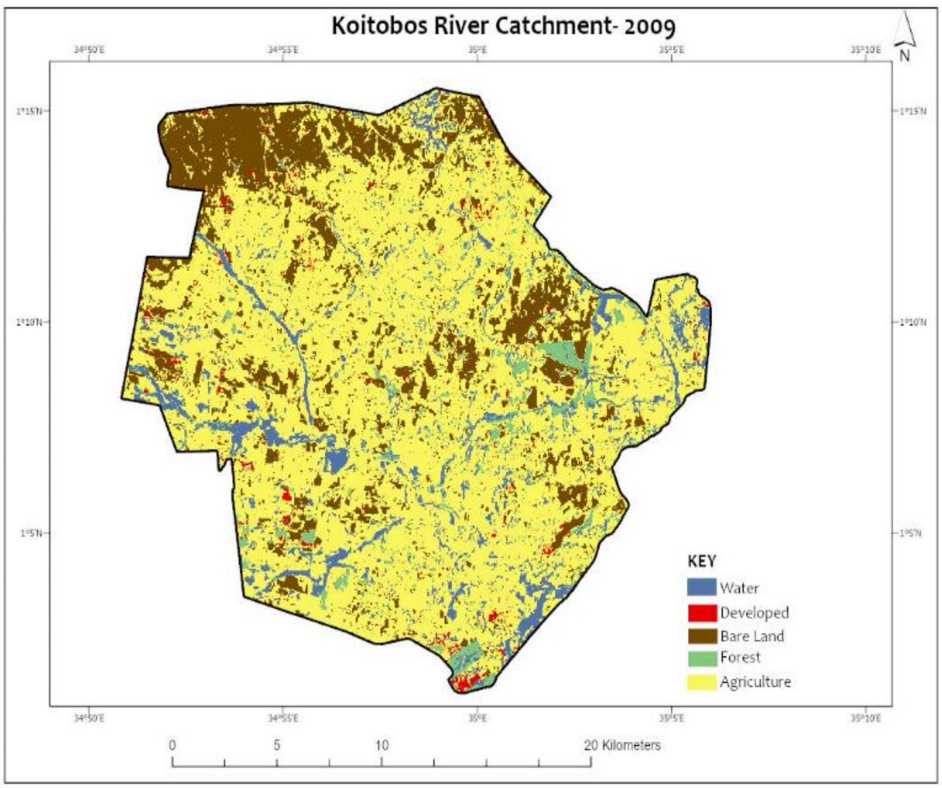

Figure – 4, Land use land cover map for year 2009

Land utilization within the study area as shown from the satellite imagery within the Koitobos river catchment in the stipulated year of assessment, 2009.

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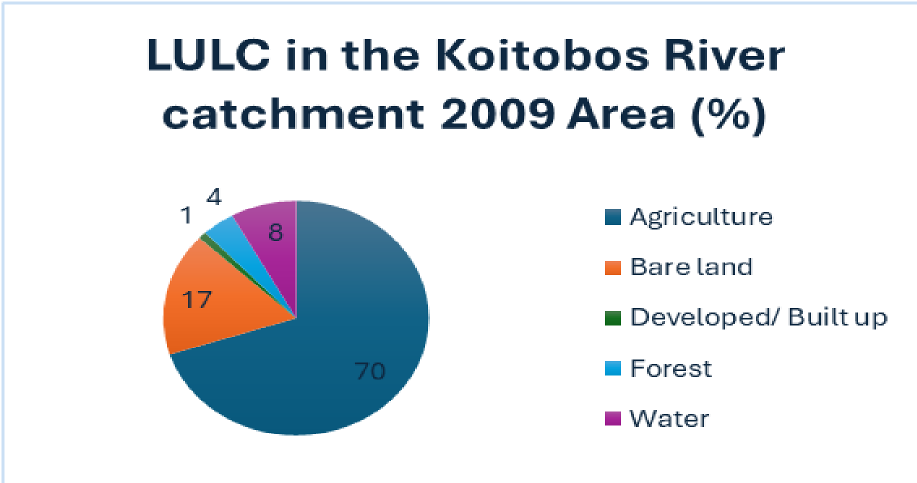

Figure – 5, **Land use land cover map for year 2009**

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 changes was Agriculture land covering 77.68% of the entire area coverage of the catchment.

The map shows the land use land cover for the year 2022.

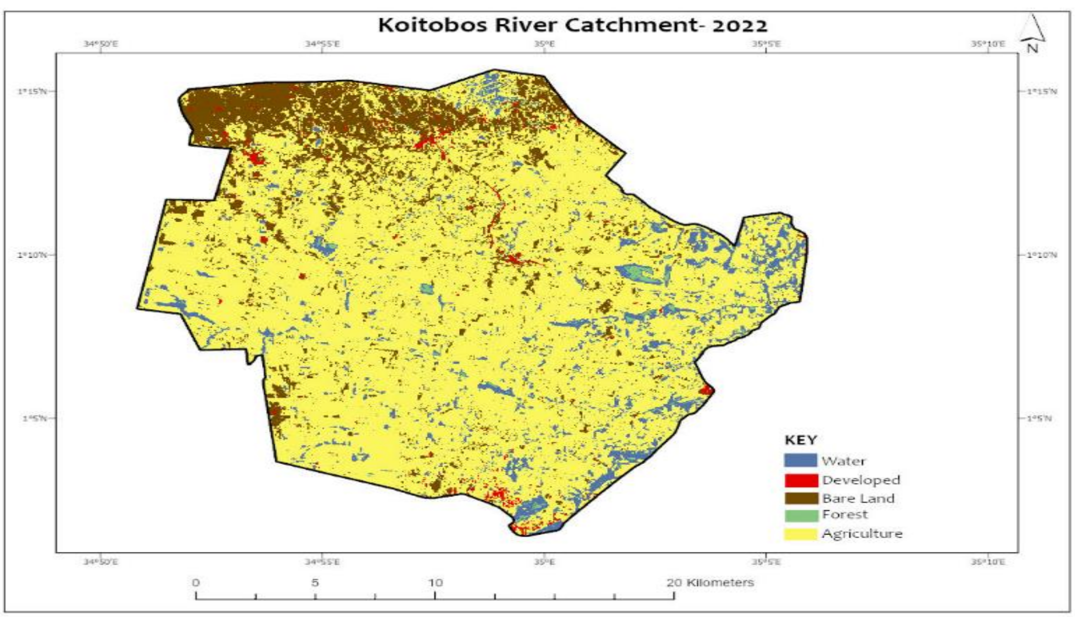

Figure – 6, **Land use land cover map for year 2022**

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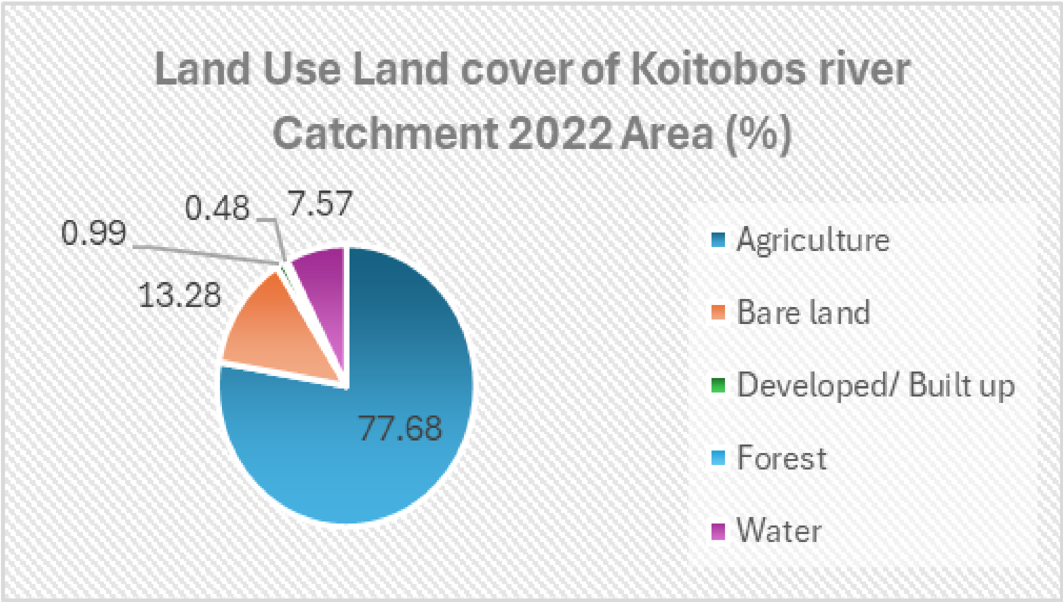

Figure – 7, **Land use land cover map for year 2022**

Accuracy assessment results for the year 1995

Accuracy Assessment was performed to ensure that the output from classification was the same as to what was on the ground. This process was done with the help of reference data. The study used two kinds of data which included the ground truth GPS points collected randomly from the ground, aerial image acquired and Google earth image which has an archive of images covering the period of study. The producers, users and overall accuracy were then determined for all the land use land cover types identified for the years under study.

Overall accuracies and Kappa coefficient

	1995	**2009**	**2022**
Overall Accuracy	78.94	86.68	85.71
Kappa Coefficient	73.42	82.99	81.42

The overall accuracies are a measure of total correctly classified samples with respect to the entire number of samples while kappa coefficient was a measure between interpreted image and the reference data. The kappa coefficient showed that the percentages of 0.7342, 0.8299 and 0.8142 for years 1995, 2009 and 2022 respectively fall within accepted score which were high scores as far as the computation of accuracies was concerned.

Extent of land use, land cover changes in Koitobos River catchment

The study findings revealed that different farming system were undertaken within Koitobos river catchment, among them being cultivation across the contour and along the contour while other farming practices identified were the traditional method of broadcasting, including manual and mechanized method and most of the respondents plough their farms twice and planted crops over the two seasons. Among the trees planted, eucalyptus was favorable for long term while Sesbania was favorable for short-term trees.

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.

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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, indiscriminate or excessive clearing of forest or vegetation and other land use and land cover-based activities.

Land use land cover change evaluations for the future within Koitobos River catchment.

The study findings revealed that farming systems were improving through the application sustainable land management practices while road networks and community social standards were highly deteriorating. The residents of the Koitobos river basin had not been well sensitized on programs initiated along the catchment, it was also noted that projects in the catchment were run by the government, non-governmental organizations and faith-based organizations which were focusing on the well-being of the people within the catchment. It was realized that projections on population increase exerted pressure on land change and land cover thus influencing river catchment due to land sub-division which reflects to be changing tremendously within the catchment area depicting that in future pressure on the on the land resources will increase. It was also noted that increased unsustainable human activities will impact on land cover land change within the river catchment and the climatic changes will influence food security, which will in turn be a determining factor of land use, land cover land changes within the river catchment. 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. This should be done in a competition manner that the village which will perform well should be given some incentives. 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 indicates 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.

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CONCLUSION

The overall objective of the study was to assess the temporal and spatial land use and land cover changes within Koitobos River catchment in Trans Nzoia County, Kenya. These resulted in the three main conclusions as follows: -
Firstly, the study concluded that an integrated watershed management approaches have to be employed such as application of integrated agroforestry systems, integrated soil fertility management practices, good agricultural practices with integrated pest management technologies and soil and water management measures encompass with conservation agriculture.

Secondly, through the analysis of the main sources of water used by the residents. The study concluded that most of the inhabitants of Koitobos catchment area experienced drying of the water springs and reduced river volumes throughout the year resulting in poor farming activities in the catchment area. Additionally, the increased frequency in the flooding patterns due to the variations in rainfall intensity affected land use resulting in land cover changes.

Finally, the study concluded that farming systems were improving through the application of sustainable agricultural land management practices, however, road infrastructure and community social standards were highly deteriorating. These coupled with population increase exerted pressure on land use change and land cover thus influencing river catchment due to land sub-division which predicted future pressure on the land resources.

The study therefore concluded that establishment of sustainable soil and water management measures together with adoption of sustainable land management practices will sustainably heal the land and conserve biodiversity within Koitobos river catchment. This was corroborated by Mubea et al., (2010), in their works that purposed to determine the long-term hydrological influence of Land use, land cover change in the Little River watershed in Tennessee, revealing that the changes in Land Use from forest land to agricultural land led to increase in runoff and thus increase in river discharge during the wet months. During the dry months, the flow was very low in agricultural lands because the underground aquifers were not replenished during the wet months due to excessive runoff. The forested areas on the other hand were opposite to that of the agricultural land. Under this situation, the infiltration occurred during the rainy season and thus the river discharge was normal.

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.

Policy recommendations

The following recommendations made were directly linked to non-existent policies that needed to be formulated or policies that existed but were not being properly implemented nor reinforced.

Firstly, the study recommended the need for establishment of sustainable soil and water management measures such as building of gabions, integration and planting agroforestry trees along the riverbanks, riparian areas, and terracing on-farms with adoption of sustainable land management practices on farms that sustainably heal the land and uphold biodiversity conservation.

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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 in protecting and conserving biodiversity within the Koitobos river catchment.

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.

Recommendations for good practice

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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