American Journal of Geospatial Technology (AJGT)

ISSN: 2833-8006 (ONLINE)

VOLUME 5 ISSUE 1 (2026)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Geospatial Technology (AJGT)

Volume 5 Issue 1, Year 2026
ISSN: 2833-8006 (Online)
DOI: https://doi.org/10.54536/ajgt.v5i1.8320
https://journals.e-palli.com/home/index.php/ajgt

Spatiotemporal Assessment of Land Use and Land Cover Change Effects on Eco- Hydroclimatic Conditions in Kiambu County, Kenya

Pauline Angerlyline Wamalwa[1*], Samson Mabwoga[1], Charity Konana[1]

Article Information

Received: May 24, 2026

Accepted: August 08, 2026

Published: September 14, 2026

Keywords

GIS - Geographic Information Systems, LST - Land Surface Temperature, NDVI - Normalized Difference Vegetation Index, RS - Remote Sensing

ABSTRACT

Increasing land-use transitions are major drivers of eco-hydroclimatic changes, particularly in rapidly growing urban areas. This study therefore sought to assess the spatiotemporal effects of land use changes on eco-hydroclimatic conditions in Kiambu County, utilizing remote sensing and Geographic Information Systems technologies. Landsat satellite imagery from 2004 and 2024 was used. Rainfall data, Land Surface Temperature (LST), and Normalized Difference Vegetation Index (NDVI) were used to assess variations in vegetation cover, thermal patterns, and precipitation trends. Land use and land cover maps were generated using supervised classification, and accuracy assessments were performed to validate the classified maps. Statistical analyses were conducted to examine the relationships between LULC dynamics and eco-hydroclimatic parameters. The findings showed a significant expansion of built-up areas, accompanied by declines in cultivated land, vegetation cover, and water bodies. These changes were associated with increased LST, reduced vegetation health, and alterations in rainfall patterns. The study further demonstrated that increased urbanization and substantial landscape changes have significantly affected the county's eco-hydroclimatic conditions. These changes have significant implications for environmental sustainability, water resources, climate change adaptation and resilience, and land use planning at the county level. The findings are expected to provide evidence to support informed policy formulation and sustainable spatial planning aimed at enhancing ecological resilience in Kiambu County.

INTRODUCTION

Land use and land cover change has become one of the most iconic drivers of environmental changes globally, predominantly in fast growing regions where natural landscapes are being converted into agricultural land, built-up lands, and infrastructure development (Masayi *et al.*, 2021; Kogo *et al.*, 2020). The changes directly affect ecological integrity and hydroclimatic processes by changing vegetative zones, soil physical characteristics, water cycles, and local climatic patterns (Kogo *et al.*, 2020). The advancement in GIS and RS technologies have greatly improved the ability to monitor and quantify spatiotemporal changes in land use and land cover (Masayi *et al.*, 2021). Globally, urban sprawl due to increased population growth, intensification in agricultural activities, and industrial expansion has led to the conversion of forest lands, wetlands, grasslands, and agricultural land areas into built-up environments, changing the landscape (Willkomm *et al.*, 2021). According to Kogo *et al.* (2020), such alterations have profound effects on ecological and hydroclimatic systems. The effects include; increased LST, declining NDVI, reduced groundwater recharge, changes in rainfall trends, increased food insecurity, and increased flood risks (Willkomm *et al.*, 2021; Masayi *et al.*, 2021; Kogo *et al.*, 2020). Furthermore, assessing the correlation between LULCCs and eco-hydroclimatic conditions has become the priority of most research studied worldwide (Willkomm *et al.*, 2021).

In sub-Saharan Africa, increased population has resulted into increased urbanization that is occurring at an unprecedented rate (Karaya *et al.*, 2021; Petersen *et al.*, 2021), often without proper land-use planning (Petersen *et al.*, 2021). Many cities in African countries have experienced substantial conversion of agricultural land use, forests, and wetlands into residential land use, commercial, and industrial developments (Petersen *et al.*, 2021). These changes in land use have led to environmental degradation, loss of biodiversity, water shortage, and vulnerability to climate-related hazards such as floods (Karaya *et al.*, 2021; Petersen *et al.*, 2021).

Kenya has experienced significant land use and land cover alterations over the past two decades due to increased population growth, urban growth, agricultural growth, and infrastructure development (Petersen, Bergmann and Nüsser, 2021; Ondiek *et al.* 2020; Kogo, Kumar and Koech, 2020). The growth of urban centers has increasingly encroached in forests areas, cultivated land, and wetlands, resulting in altered ecological processes and hydroclimatic variability (Ondiek *et al.* 2020). Studies conducted in different regions of Kenya have reported that Land Use Land Cover changes contribute to soil erosion, loss of biodiversity, changes in river direction, reduced NDVI, and increased LST (Kogo *et al.*, 2020; Masayi *et al.*, 2021). Several studies have been carried out

[1] Maasai Mara University School of Natural Resources, Environmental Studies and Agriculture and the Department of Environmental Studies, Geography and Planning, Kenya
[*] Corresponding author's e-mail: angiepauline100@gmail.com

in Kenya, Waithaka, Murimi & Obiero (2020) carried out a study on Land use Land Cover Changes in river Ruiru Watershed, Kiambu County using GIS and RS and the key findings were Land Use Land Cover changes significantly altered watershed discharge and hydrological characteristics in the watershed. Ondiek *et al.* (2020) carried out a study on Land Use Land Cover Changes in Anyiko Wetland in Kenya and the key findings were Socio-economic activities accelerated wetland degradation and land cover transformation. Masayi, Omondi and Tsingalia (2021) carried out a study on Land Use Land Cover changes in Mt. Elgon Forest in Kenya and the key findings where forests are being converted into built-up areas thus reducing ecosystem integrity and biodiversity.

Despite the increase in research studies on land use and land cover change in Kenya, most prevailing studies have focused on individual environmental, only a handful of the studies have expansively integrated land use dynamics with hydroclimatic variables within areas that are growing fast due to urbanization like Kiambu. Moreover, few studies have concurrently examined the collective effects of LULC change on vegetation dynamics, LST, and rainfall changes using geospatial technologies over several decades. This forms an important knowledge gap for planners and policymakers who needs evidence-based strategies for sustainable urban planning and environmental management.

Therefore, this study sought to undertake a spatiotemporal assessment of land use and land cover change effects on eco-hydroclimatic conditions in Kiambu County in Kenya, using GIS, RS, and climate datasets. The study also sought to test the null hypothesis H0, there is no relationship between land use land cover changes in Kiambu County and climatic variables.

Problem of the statement

In Kenya, many scholars (Tsingalia, 2021; Ondiek *et al.*, 2020; Kogo *et al.*, 2020; Masayi *et al.*, 2021) have carried out research on land use and land cover (LULC) change. Most studies have surveyed specific environmental aspect such as hydrological degradation, soil erosion degradation, forest cover, or watershed management. Very few studies have expansively assessed how LULC changes concurrently influence eco-hydroclimatic trends, mostly NDVI dynamics, LST, and rainfall changes, in rapidly growing areas such as Kiambu County. As urban growth continues to replace other land uses and changing the landscape, the resultant environmental degradation remains inadequately quantified, restraining the convenience of scientific evidence that are required for sustainable landscape planning and climate adaptation. This knowledge gap delays the formulation of effective policies for balancing urban sprawl with sustainable ecosystem conservation. Therefore, this study sought to assess the spatiotemporal effects of land use and land cover change on eco-hydroclimatic conditions in Kiambu County in Kenya, using GIS, remote sensing, and climate data.

MATERIALS AND METHODS

Study Area

Kiambu County is positioned in central Kenya, neighboring Nairobi City County to the south. It occupies approximately 2,449 km² and is made up of 13 sub-counties. Due to its close proximity to Nairobi County, Kiambu county has experienced rapid urbanization, leading to the conversion of agricultural areas, forest lands, and open spaces into residential landscape, commercial areas, and industrial expansions. These land use changes expose the area to the impacts. Kiambu county has a sub-humid tropical highland climate. The mean annual temperatures range from 16°C - 26°C and annual rainfall ranges between 800 - 2,000 mm. Long rains occur from March to May and short rains from October to December. Kiambu county has diverse vegetation cover, variety of fertile soils, and several rivers that support agriculture. Besides these, rapid urban growth is a threat to NDVI coverage, LST and rainfall pattens. These features places Kiambu County at a suitable place for investigating the effects of LULC change on eco-hydroclimatic conditions using GIS and remote sensing.

Research Design

The study implemented a quantitative spatiotemporal research design utilizing GIS, RS, and statistical techniques. Historical the study used satellite images and climatic datasets to analyze the datasets and determine the changes in land use and land cover and their impacts on NDVI dynamics, LST, and rainfall patterns between 2004 and 2024.

The study obtained data from Landsat 7 ETM+ 2004 and Landsat 8/9 OLI/TIRS 2024 for land cover classification maps. The data from Google Earth was used for ground truthing and validating the classified maps. The study also used CHIRPS for rainfall data, and WorldClim for temperature data. The datasets underwent image pre-processing and post- processing for image corrections. The study carried out eco-hydroclimatic assessment to obtain maps, tables and graphs.

Methodological flowchart

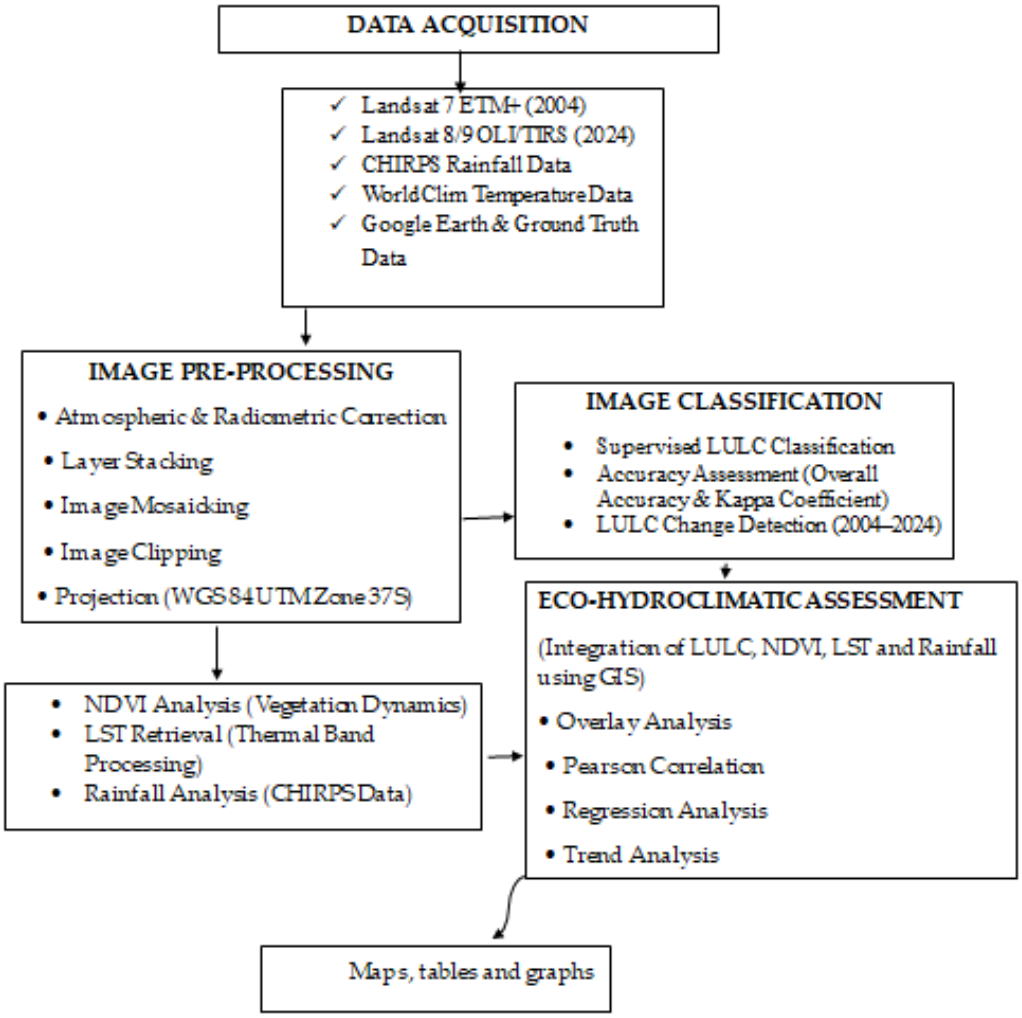

Figure1: Methodological flowchart

RESULTS AND DISCUSSIONS

The study carried out land use classification maps utilizing Landsat 7 ETM+ 2004 and Landsat 8/9 OLI/TIRS 2024. The land sat underwent both atmospheric and radiometric corrections. The post-processing process were done to filter the salt and pepper from the classified

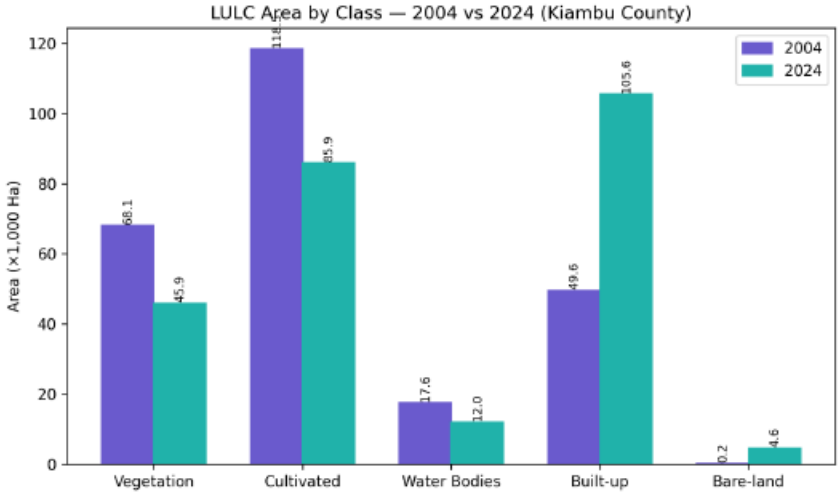

Figure 2: Land use for 2004 and 2024

maps. The study classified the land use into 5 classes that included; Bare lands, vegetative lands, cultivated lands, built-up areas and water bodies.

The study results showed a decline in vegetation lands, cultivated areas, water bodies and an increase in built-up areas and bare lands. The study results correlated with the study by; Hamal & Shahnawaz (2024), that used supervised classification and the results revealed a drop in agricultural lands and an increase in built-up areas.

The study carried out the currency assessment for the two years; Overall Accuracy (%) was 94 % and 92% for 2004 and 2024 respectively and Kappa Coefficient was 0.93 and 0.9882 for 2004 and 2024 respectively. The study results showed similarities with the research by Odhiambo, Mwasi & Ngetich (2024) on Sentinel-2 that revealed an Overall Accuracy of 91.67% and a Kappa coefficient of 0.90 on urban land use within Eldoret city. The study utilized climatic data from CHIRPS, WorldClim, and NDVI to show the effects of land use land cover changes on eco- hydroclimatic conditions. In Kiambu County the NDVI showed a decline of high 0.63 index and low -0.25. This is a reflection of unhealthy vegetation cover in 2024. Kiambu county also showed anomalies in LST in 2024 and general increase in temperatures across the 12 months in the County.

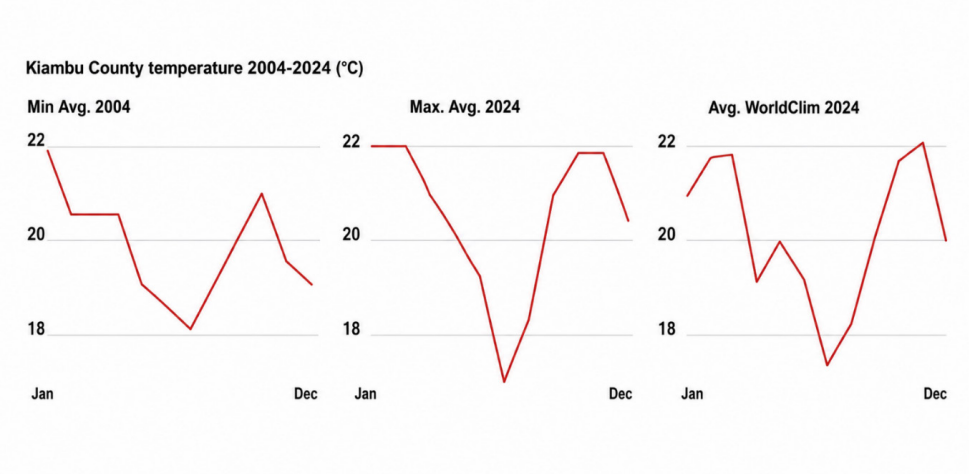

Figure 3: Max, Min, avg and avg WorldClim temperature for 2004 and 2024

From figure 3 there was an increase in the annual mean temperature from 19.80°C in 2004 to 20.62°C in 2024, and this exceeded the WorldClim temperature of 2024 mean of 20.23°C. Majority of months showed temperatures close to or more than the climatological average temperature. For instance, January was higher with +1.42°C and April +2.00°C displaying the strongest positive anomalies. This study results showed that Kiambu County has witnessed an overall warming trend over the past two decades. Figure 4 shows that Kiambu county had a negative linear correlation between the NDVI and LST with R2 = 0.9471 and Pearson r = - 0.9732. The study correlated with IPCC, (2023) that found out that due to pre-industrial activities related to land use land cover changes and increase in built-up areas, the global land surface temperature has increased by 1.1°C.

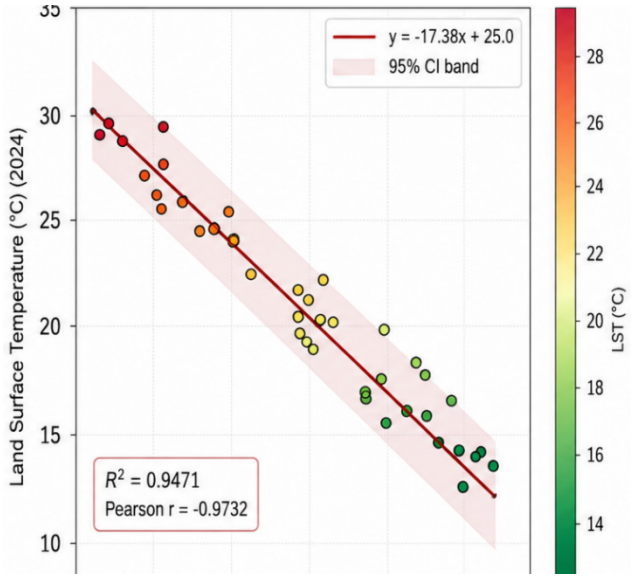

Figure 4: NDVI vs LST Negative Linear Correlation of Kiambu County

The study employed CHIRPS for rainfall dataset to show the variations in Kiambu rainfall patterns. The study results showed a clear bimodal rainfall in Kiambu County between 2004 and 2024. Long rains were visible in March–May, and more was witnessed in April, and the dry period was witnessed from June to September. Short rains were witnessed in October–December. There was a close relationship between the observed rainfall datasets and the CHIRPS rainfall datasets providing a reliable picture of monthly rainfall variability and can be confidently be used for hydro-climatic and environmental studies in Kiambu County.

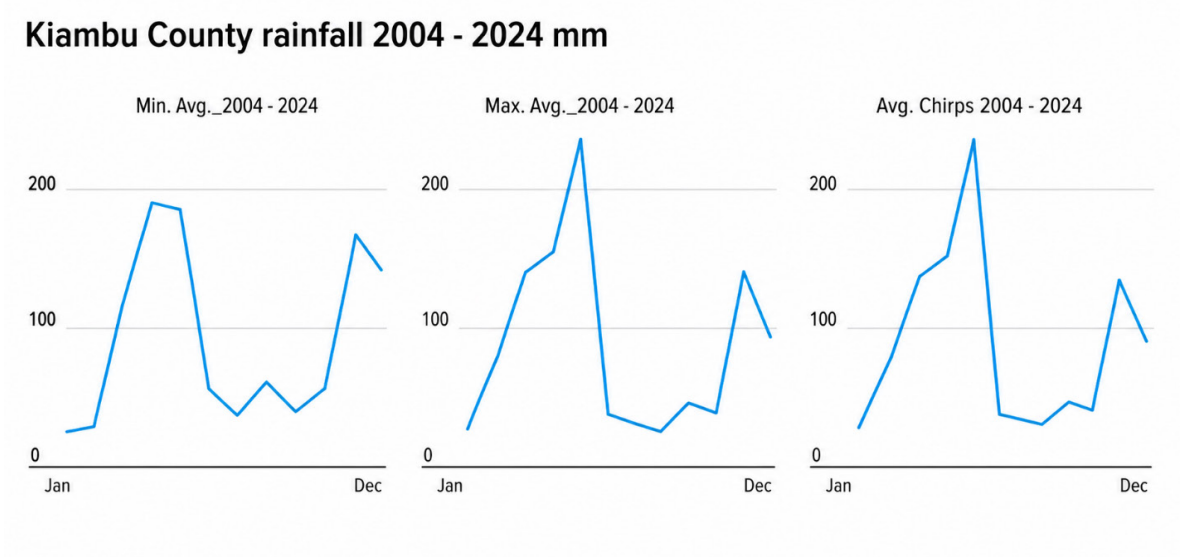

Figure 5: Max, Min, avg and avg CHIRPS rainfall for 2004 and 2024

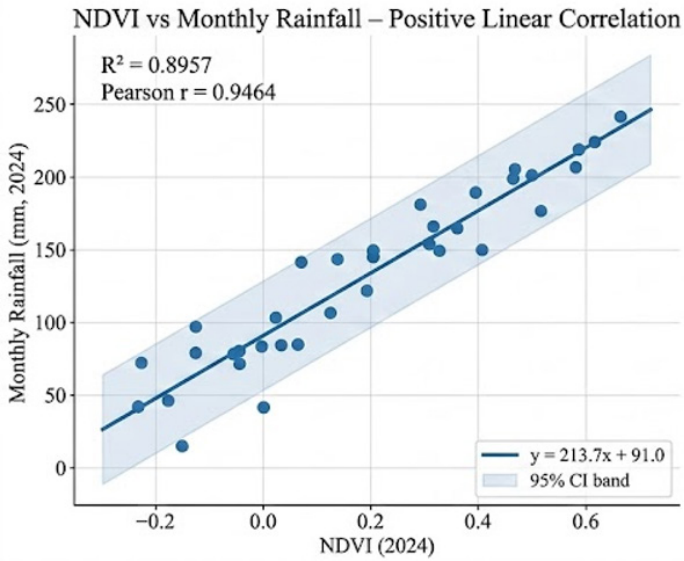

Figure 6: NDVI vs Monthly Rainfall: Linear Positive Correlation

The Figure 6 demonstrated that NDVI is strongly influenced by Kiambu County rainfall as seen by R2 = 0.8957 and r= 0.9464. The wet season supports more vigorous vegetation growth compared to dry ones. The strong correlation confirms that rainfall is a key driver of vegetation dynamics in the county, making NDVI a useful indicator for monitoring eco-hydroclimatic conditions and assessing the effects of land use and land cover changes on ecosystem productivity. In coming up with eco-hydroclimatic maps the study used NDVI, LST, rainfall and LULC datasets utilizing the same weights of 0.25 of each dataset. The study correlated with Zhang & Gao (2025) that found out that land use land cover changes have a strong impact on precipitation, with increase in urbanization, there is a decrease in vegetative cover (NDVI) leading to reduction in evapotranspiration leading to the changes in the rainfall trends. The study by Aholi, Obiero & Makokha (2026), also revealed that land use land cover changes have influenced climate variability in parts of Western Kenya. The study by Pauline, (2025) revealed that land use land cover changes in Nairobi County is a contributor to climatic variability accompanied by flash flood rains that causes a lot of havoc including deaths.

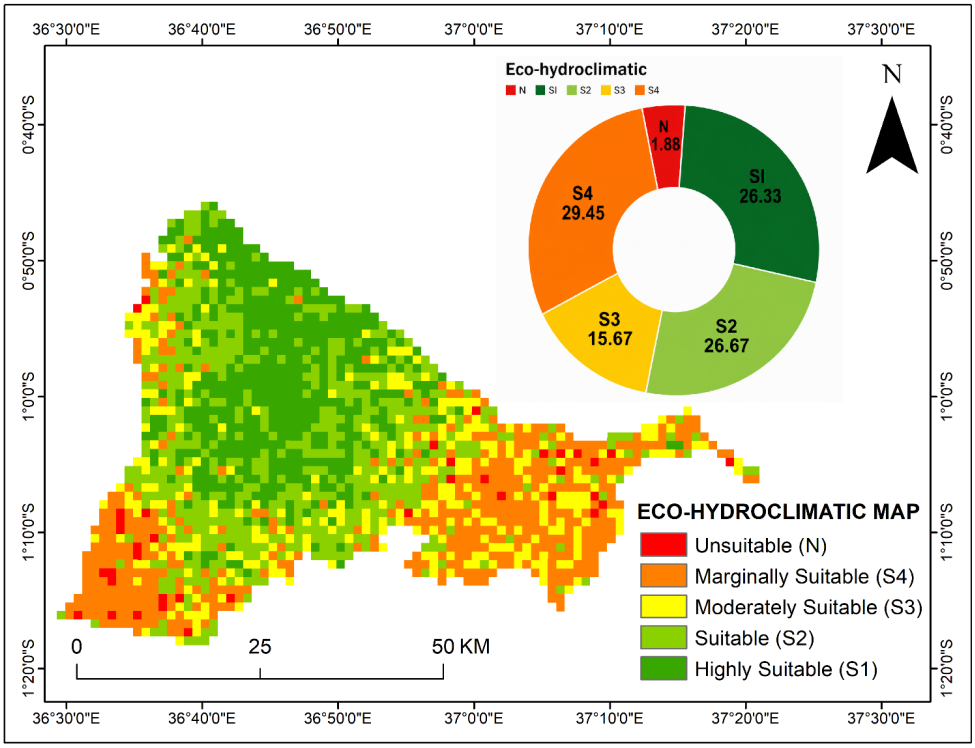

Figure 7: Eco-hydroclimatic maps

The study results revealed that climatic conditions of Kiambu county are shifting with areas of high built-up showing marginal and unsuitable climatic conditions of 31.33%. The agricultural and cultivated zones are on a reduction trend as seen by 26.33% and moderately suitable gave 15.67%. The results indicate that if the future land use changes will not be practiced sustainable, then the temperatures and rainfall in Kiambu County will shift leading to a decline in NDVI. This study relates to the study by Keizer *et al.* (2016), who incorporated vegetation and water quality datasets in creating an Eco-hydroclimatic map and the findings were identification of how the groundwater and floodwater influence vegetation distribution. Wanjala *et al.* (2018) also carried out the related study on application of ecohydrological tools in Lake Naivasha and the key findings were development of ecohydrological management strategies is sustainable land use land cover changes. Therefore, the H0 hypothesis, there is no relationship between land use land cover changes in Kiambu Couty and climatic dataset was rejected and the alternative hypothesis, there relationship between land use land cover changes in Kiambu Couty and climatic dataset accepted. To validate the eco-hydroclimatic model, a sensitivity analysis was conducted using three different scenarios. The scenarios involved varying the relative weights assigned to the eco-hydroclimatic model criteria to assess the robustness and stability of the model under different weighting

Table 1: Sensitivity Analysis

Eco-hydroclimatic Classes	**Equal weights (%)**	**Climatic primacy (%)**	**Environmental primacy (%)**
Unsuitable (N)	1.88	11.18	12.40
Marginally Suitable (S4)	29.45	21.90	24.48
Moderately Suitable (S3)	15.67	31.91	20.49
Suitable (S2)	26.67	19.44	20.51
Highly Suitable (S1)	26.33	15.56	22.12
Total	**100.00**	**100.00**	**100.00**

conditions. The results obtained from the three scenarios were shown in table 1:

The table below presents the sensitivity analysis under three different weighting scenarios. The equal-weight scenario assigned a weight of 0.25 to each criterion. The climatic-primacy scenario assigned greater weights of 0.40 and 0.30 to LST and rainfall, respectively, while the environmental/land-cover primacy scenario assigned greater weights of 0.40 and 0.30 to LULC and NDVI, respectively. In overall, the sensitivity analysis demonstrated that the eco-hydroclimatic suitability model is sensitive to the relative weighting of climatic and environmental criteria. However, the model did not produce a completely different suitability structure under each scenario, indicating a degree of robustness in the overall spatial pattern.

CONCLUSION

The study results showed that LULC changes have greatly affected Kiambu county's eco-hydroclimatic environments. Areas occupied with dense vegetation showed lower LST and fairly the rainfall was higher compared to areas that were highly urbanized with little vegetation cover.

There was a strong negative relationship between NDVI and LST that confirmed the important role played with NDVI in regulating LST, however, the positive relationship between NDVI and rainfall confirmed the importance of NDVI in sustaining the local hydroclimatic processes.

Recommendations

The study proposes the following recommendations:

1. The integration of eco-hydroclimatic suitability maps by county governments into their county spatial plans, Integrated Development Plans (CIDPs) and urban development strategies for sustainable infrastructure development.
2. Kiambu county government should promote the Climate-smart agricultural practices to improve agricultural productivity and minimize environmental degradation.
3. Kiambu county government should encourage afforestation, reforestation and urban greening programmes to reduce LST and regularize the rainfall patterns.
4. Kiambu county government should invest in community awareness on the programmes that encourages sustainable land management practices.

Recommendations for Further Research

1. Assessment on the impacts of land use land cover change on ecosystem services, such as groundwater recharge, carbon sequestration, biodiversity conservation, flood regulation and water quality.
2. Future studies should incorporate higher-resolution satellite imagery to improve land cover classification accuracy.

Acknowledgment

First and foremost, I give all glory, honor, and sincere gratitude to Almighty God for His unfailing grace, wisdom, strength, protection, and guidance throughout my academic journey and the successful completion of this study.

I extend my heartfelt appreciation to Maasai Mara University, particularly the School of Natural Resources, Environmental Studies and Agriculture and the Department of Environmental Studies, Geography and Planning, for providing an enabling academic environment, invaluable guidance, and institutional support, especially from my supervisors Dr. Samson Mabwoga and Dr. Charity Konana.

I am equally grateful to the Regional Centre for Mapping of Resources for Development (RCMRD), especially the training Section, Department of GIS, Remote Sensing and Survey, for their technical support, professional mentorship, and access to geospatial resources that greatly enriched this research.

My sincere thanks also go to all individuals and institutions that provided financial support, whose generosity made this work possible.

Finally, I express my deepest gratitude to my beloved family members for their unwavering love, encouragement, patience, prayers, and sacrifices, which gave me the strength and determination to complete this study.

REFERENCES

Aholi, J., Obiero, K., & Makokha, M. (2026). Effect of climate variability on rainfall dynamics in a river basin: Implications for sustainable water resources utilization. *International Journal of Environment and Geoinformatics, 13*(2), 129–135. https://doi.org/10.26650/ijegeo.1861107

Hamal, M., & Shahnawaz. (2024). Comparison of the direct supervised classification and segment mean shift classification: A case study of Hetauda Sub-Metropolitan City of Nepal. *Journal on Geoinformatics, Nepal, 23*(1), 35–47. https://doi.org/10.3126/njg.v23i1.66048

Intergovernmental Panel on Climate Change. (2023). *Climate change 2023: Synthesis report.* IPCC. https://doi.org/10.59327/IPCC/AR6-9789291691647

Karaya, R. N., Onyango, C. A., Ogendi, G. M., & Tejada Moral, M. (2021). A community-GIS supported dryland use and cover change assessment: The case of the Njemps flats in Kenya. *Cogent Food & Agriculture, 7*(1), Article 1872852. https://doi.org/10.1080/23311932.2021.1872852

Keizer, F. M., Schot, P. P., Okruszko, T., & Wassen, M. J. (2016). Landscape-scale ecohydrological mapping demonstrating how flood inundation water quality types relate to floodplain vegetation communities. *Ecohydrology, 9*(8), 1539–1553. https://doi.org/10.1002/eco.1746

Kogo, B. K., Kumar, L., & Koech, R. (2021). Climate change and variability in Kenya: A review of

impacts on agriculture and food security. *Environment, Development and Sustainability, 23(*1), 23–43. https://doi.org/10.1007/s10668-020-00589-1

Masayi, N. N., Omondi, P., & Tsingalia, M. (2021). Assessment of land use and land cover changes in Kenya's Mt. Elgon forest ecosystem. *African Journal of Ecology, 59*(4), 988–1003. https://doi.org/10.1111/aje.12886

Odhiambo, S., Mwasi, B., & Ngetich, J. (2024). Capability of rule-based classification technique in identifying sprawl areas: A case study of areas around Eldoret Town, Kenya. *African Journal of Science, Technology and Engineering, 4*(1), 25–34.

Owino, C. N. N., Kitaka, N. K., Kipkemboi, J. K., & Ondiek, R. A. (2020). Assessment of greenhouse gases emission in smallholder rice paddies converted from Anyiko Wetland, Kenya. *Frontiers in Environmental Science, 8*, Article 80. https://doi.org/10.3389/fenvs.2020.00080

Petersen, M., Bergmann, C., Roden, P., & Nüsser, M. (2021). Contextualizing land-use and land-cover change with local knowledge: A case study from Pokot Central, Kenya. *Land Degradation & Development, 32*(10), 2992–3007. https://doi.org/10.1002/ldr.3961

Waithaka, A., Murimi, S., & Obiero, K. (2020). Assessing the effects of land use/land cover change on discharge using SWAT model in River Ruiru watershed, Kiambu County, Kenya. *Applied Ecology and Environmental Sciences, 8*(5), 303–314. https://doi.org/10.12691/aees-8-5-18

Wamalwa, P. A. (2025). Menace of flash floods in urban areas: A case study of Nairobi County. *African Journal on Land Policy and Geospatial Sciences, 8*(6), 1047–1054. https://doi.org/10.48346/IMIST.PRSM/ajlp-gs.v8i6.53139

Wanjala, S., Mwinami, T., Harper, D. M., Morrison, E. H. J., & Pacini, N. (2018). Ecohydrological tools for the preservation and enhancement of ecosystem services in the Naivasha Basin, Kenya. *Ecohydrology & Hydrobiology, 18*(2), 155–173. https://doi.org/10.1016/j.ecohyd.2017.09.004

Willkomm, M., Follmann, A., & Dannenberg, P. (2021). Between replacement and intensification: Spatiotemporal dynamics of different land use types of urban and peri-urban agriculture under rapid urban growth in Nakuru, Kenya. *The Professional Geographer, 73*(2), 186–199. https://doi.org/10.1080/00330124.2020.1835500

Zhang, M., Gao, Y., & Ge, J. (2025). Different responses of extreme and mean precipitation to land use and land cover changes. *npj Climate and Atmospheric Science, 8*, Article 175. https://doi.org/10.1038/s41612-025-01049-1