Unregulated Sprawl and the Urban Flood Paradox: Analyzing the Spatial Dimensions of Urban Growth and Climate Vulnerability in Kitui Town

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Abstract

Kitui Town, a secondary urban center in eastern Kenya's arid and semi-arid lands (ASALs), has undergone rapid, largely unplanned spatial expansion over the past two decades. However, the mechanisms through which this growth intensifies local climate vulnerability remain under-researched. This study utilized a mixed-methods approach, combining remote sensing/GIS spatial analysis of Landsat imagery (2005–2025) with a descriptive survey of 384 households, 20 key informant interviews, and four focus group discussions. Findings reveal a dramatic 242.69% increase in built-up area, expanding from 12.18 km² to 41.74 km², primarily at the expense of wetlands, forests, and croplands. This expansion is strongly correlated (r=0.984*r*=0.984) with a 1.7°C rise in mean annual temperature, signaling a pronounced Urban Heat Island (UHI) effect. Furthermore, the study identifies an Urban Flood Paradox, where flood risk has escalated despite declining rainfall due to a 24% loss of wetlands and a surge in impervious surfaces. Planning systems were found to be operationally deficient, with only 10.9% of residents perceiving consistent policy enforcement. The study concludes that unregulated urban growth is the primary driver of climate vulnerability in Kitui and recommends the urgent adoption of Sustainable Urban Drainage Systems (SUDS) and strict enforcement of riparian buffer zones.

Keywords: *Urban sprawl, Land use change, Climate vulnerability, Urban Heat Island, Urban Flood Paradox, Kenya ASALs.*

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1.0 Introduction

Urbanization is the defining feature of the 21st century, with over 50% of the global population now residing in cities a figure projected to reach 68% by 2050 (United Nations, 2019). While urban growth can drive economic modernization, it simultaneously exposes populations to heightened climate risks when development is uncontrolled (IPCC, 2023). This is particularly acute in Sub-Saharan Africa, where rapid horizontal expansion often occurs in risk-prone areas such as floodplains and steep slopes (UN-Habitat, 2022).

In Kenya, the expansion of secondary towns has frequently outpaced spatial planning capacity. Kitui Town, located in a semi-arid region, exemplifies this trend. As built-up areas encroach upon agricultural land and natural vegetation, the town is increasingly susceptible to excessive heat, erratic precipitation, and flash floods. While previous research has documented urban growth in Kenya's primate cities like Nairobi and Mombasa, there is a significant analytical gap regarding smaller, fast-growing ASAL towns. This study addresses this gap by examining the intersection of spatial expansion, land use and land cover (LULC) changes, and climate vulnerability in Kitui Town between 2005 and 2025.

2.0 Materials and Methods

The study is anchored in two complementary theories:

1. **Urban Ecology Theory:** This framework views the city as a heterogeneous ecosystem where socially and institutionally defined processes like competition and succession shape the physical environment (Park et al., 1925). It provides a lens to analyze how socioeconomic forces drive the structure of urban space.
2. **Climate Vulnerability Theory:** Anchored in the IPCC (2014) framework, this theory conceptualizes vulnerability as a function of exposure to hazards, sensitivity to impacts, and adaptive capacity. It allows for a structured investigation into how land-use transitions affect the exposure kinetics of a town under climate stress.

Methodology

Study Area

The study focused on Kitui Town (37°55′ to 38°05′ E; 1°15′ to 1°30′ S), specifically high-growth peri-urban sub-locations including Kyanika, Wikililye, Syongila, Mutune, and Ithookwe.

Research Design

A mixed-methods approach was adopted.

- **Spatial Analysis:** Multi-temporal Landsat imagery (TM, ETM+, and OLI) for 2005, 2015, and 2025 was processed using ENVI 4.7 and ArcGIS Pro. Supervised classification was used to identify seven LULC classes.
- **Climate Data:** Meteorological data (2000–2025) were sourced from the

Kitui Meteorological Station to analyze trends in Air Temperature (AT) and rainfall.

- **Survey Data:** A descriptive survey was conducted with 384 households, selected via multi-stage stratified random sampling. Qualitative depth was added through 20 Key Informant Interviews (KIIs) with physical planners and environmental experts, and four Focus Group Discussions (FGDs).

3.0 Results and Discussion

The Spatiotemporal Trajectory of Urban Expansion

GIS analysis revealed a dramatic shift in the landscape. The built-up area underwent a staggering net gain of 29.56 km², representing a 242.69% increase over the 20-year study period (Table 1).

Table 1

Land Use and Land Cover (LULC) Changes in Kitui Town (2005–2025)

LULC Class	2005 (km²)	2025 (km²)	Net Change (%)	Significance (p)
Built-up	12.18	41.74	+242.69%	< 0.001
Cropland	89.35	63.42	-29.02%	< 0.001
Wetland/Swamp	23.90	18.09	-24.31%	0.032
Forest	9.05	7.29	-19.45%	0.121

The most intense urbanization occurred between 2005 and 2015, coinciding with Kenya's post-2013 devolution, which saw increased investment in county headquarters. Survey results corroborated these findings, with 91% of respondents observing noticeable expansion in their neighborhoods.

The Thermal Dimension: Urban Heat Island (UHI) Effect

Meteorological data confirmed a consistent warming trend, with mean annual temperatures rising from 22.9°C in 2005 to 24.6°C in 2025. Statistical analysis showed a very strong positive correlation (r=0.984*r*=0.984, R2=0.969*R*2=0.969) betw een built-up growth and temperature increase.

For every 1 km² of built-up expansion, mean temperatures rose by approximately 0.055°C. This rate exceeds the national average warming rate, suggesting that local land-surface transformation is the primary driver of localized warming. Qualitative accounts

from FGDs highlighted midday unlivability, with 80% of residents perceiving the town as much hotter due to the removal of shade trees and the proliferation of iron-roofed structures.

The Urban Flood Paradox

A critical finding of this study is the Urban Flood Paradox: flood frequency and severity increased even as annual rainfall became more erratic and, in some periods, declined.

- **Mechanism 1:** The 242% increase in impervious surfaces converts rainfall directly into rapid runoff.
- **Mechanism 2:** The 24.31% decline in wetlands has eliminated natural flood pulses that previously attenuated peak flows.
- **Mechanism 3:** The 19.45% loss of forest cover has reduced soil water-holding capacity.

Survey data showed that 83% of residents experienced increased flash flooding, with 71% explicitly attributing this to the loss of swamps and wetlands. Residents noted that the water remembered where it used to go, flooding houses built on infilled seasonal wetlands.

Governance and Policy Gaps

The study identified a severe policy-practice disconnect. While Kitui possesses a comprehensive planning architecture (e.g., County Spatial Plan 2016–2026), its real-world impact is negligible.

- **Awareness:** 41.7% of residents were entirely unaware of zoning regulations.
- **Enforcement:** Only 10.9% perceived policies as consistently enforced.
- **Capacity:** The Physical Planning Department employs only 7 technical staff to oversee 30,496 km², resulting in a physical site inspection rate of less than 15% for building applications.

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4.0 Conclusion

This research demonstrates that unregulated urban expansion is the primary amplifier of climate vulnerability in Kitui Town. The transformation of the landscape from permeable vegetation to an impervious built fabric has created a self-reinforcing vulnerability cycle. The Urban Flood Paradox and UHI intensification are not merely meteorological phenomena but are outcomes of a governance system constrained by institutional deficits and political pressures.

5.0 Recommendations

1. **Stormwater Management:** The County Government should pilot Sustainable Urban Drainage Systems (SUDS), including retention ponds and bioswales, which can reduce peak runoff by 30–50%.
2. **Riparian Protection:** Strictly enforce a 30-meter mandatory riparian buffer zone on all seasonal watercourses and formally designate the remaining 18.09 km² of wetlands as Protected Ecological Zones.
3. **Urban Greening:** Implement an indigenous tree-planting program targeting a minimum of 50,000 trees by 2030 to mitigate UHI effects.
4. **Institutional Reform:** Expand the Physical Planning Department and implement a GIS-based development monitoring system to enable real-time tracking of building permits and violations.

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