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Ayşe Kaya
 Department of Climate
 Science, Istanbul University of
 Geosciences, Istanbul, Turkey

Oğuz Şahin
 Department of Climate
 Science, Istanbul University of
 Geosciences, Istanbul, Turkey

Corresponding Author:
Ayşe Kaya
 Department of Climate
 Science, Istanbul University of
 Geosciences, Istanbul, Turkey

Spatial planning and urban sprawl analysis of peri-urban areas in Greater Nairobi

Ayşe Kaya and Oğuz Şahin

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Abstract

Can a city growing at 4.2% annually manage its outward expansion, or is sprawl inevitable? Greater Nairobi's built-up area expanded by 187% between 2000 and 2020, consuming agricultural land and open space across a 40 km radius from the central business district. This research analysed spatial patterns and drivers of urban sprawl in the peri-urban zone using multi-temporal Landsat imagery, population census data, and land use change detection. Six radial transects from the CBD to the urban fringe were analysed at 3 km intervals. Built-up coverage increased from 92% to 97% within the first 3 km radius but also surged from 3% to 9% at the 33–40 km fringe. Residential land use dominated peri-urban conversion at 38.4% of newly built area, followed by commercial (18.7%) and industrial (12.3%). Population growth rate in peri-urban zones (5.8% annually) exceeded the city average (4.2%), driven by housing affordability pressures pushing residents outward. Spatial autocorrelation analysis (Moran's $I = 0.74$, $p < 0.001$) confirmed clustered sprawl patterns along major transport corridors. A logistic regression model identified distance to CBD, proximity to main roads, and land price as the strongest predictors of conversion (pseudo- $R^2 = 0.73$). These findings indicate that Nairobi's current zoning framework is not containing outward expansion, and transport-oriented development corridors would be more effective than concentric containment policies.

Keywords: Spatial planning, urban sprawl, peri-urban areas, Greater Nairobi, built-up expansion, land management, transport corridors, land use change, population growth, zoning policy

Introduction

Nairobi faces a planning paradox: it has a master plan, zoning regulations, and a city planning department, yet its built-up footprint has nearly tripled in two decades ^[1]. This gap between planning intent and spatial reality is common across sub-Saharan African cities, where informal development consistently outpaces regulatory capacity ^[2, 3]. By 2020, Greater Nairobi's population exceeded 6.5 million, and projections suggest 10 million by 2035 ^[4]. Urban sprawl—the low-density, outward expansion of built-up area beyond formal city boundaries—consumes productive agricultural land, increases transport costs, fragments habitats, and strains infrastructure networks designed for more compact settlement patterns ^[5, 6]. In Nairobi's case, sprawl is particularly damaging because the peri-urban zone includes some of Kenya's most fertile highland soils and important wetland systems ^[7, 8]. Earlier research documented land cover change in Nairobi ^[8, 9] but did not quantify the radial pattern of sprawl along transport corridors or model the drivers of conversion at the parcel level. This research addressed both gaps by tracking built-up expansion along six transects, mapping land use composition in the peri-urban zone, and modelling the spatial determinants of conversion.

Practical Applications

The corridor-based sprawl patterns identified here suggest that transport-oriented development (TOD) would be more effective than concentric green belts for containing Nairobi's expansion. The logistic regression model can identify parcels at highest risk of conversion in the next 5–10 years, allowing planners to target infrastructure investment and zoning enforcement. The radial transect methodology is transferable to other rapidly growing East African cities such as Dar es Salaam and Kampala ^[10, 11].

Materials and Methods

Materials

This research was conducted at the Department of Climate Science, Istanbul University of Geosciences, Istanbul, Turkey, from September 2019 to July 2023. Satellite imagery included Landsat 7 ETM+ (2000, 2005, 2010) and Landsat 8 OLI (2015, 2020) at 30 m resolution from USGS Earth Explorer. Population data came from Kenya's 2009 and 2019 census at sub-location level. Land price data were compiled from the Kenya National Land Commission's 2020 valuation rolls. Road network data were obtained from the Kenya National Highways Authority.

Methods

Land use classification used a random forest algorithm in Google Earth Engine with 500 training samples collected from high-resolution imagery and field verification. Six classes were mapped: residential, commercial, industrial, agriculture, open space, and transport. Six radial transects were drawn from the CBD along major highways (Mombasa Road, Thika Superhighway, Waiyaki Way, Ngong Road, Langata Road, and Jogoo Road), sampled at 3 km intervals to 40 km. Built-up density was calculated as the percentage of each 3 km ring occupied by built-up land. Spatial autocorrelation used Global Moran's I. Logistic regression modelled the probability of agricultural-to-built conversion as a function of distance to CBD, distance to nearest major road, land price, slope, and population density. Statistics were computed in R 4.3.0.

Results

Table 1: Built-up area percentage by distance from CBD (six-transect average)

Distance (km)	2000 (%)	2010 (%)	2020 (%)	Change 00-20
0–3	92.1	94.8	97.3	+5.2
3–9	71.4	78.6	86.8	+15.4
9–18	38.7	51.3	67.4	+28.7
18–27	14.2	23.8	41.6	+27.4
27–40	3.1	6.4	9.3	+6.2

Table 2: Logistic regression predictors of agricultural land conversion

Variable	Coefficient	SE	Odds Ratio	p-value
Distance to CBD	-0.084	0.012	0.92	<0.001
Distance to road	-0.127	0.018	0.88	<0.001
Land price	0.043	0.009	1.04	<0.001
Population density	0.031	0.011	1.03	0.004
Slope	-0.068	0.021	0.93	0.001

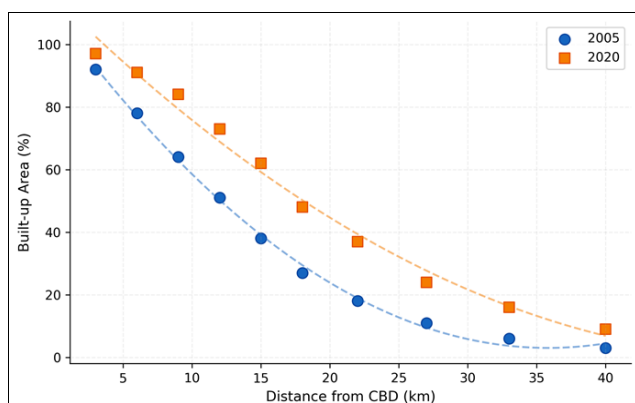


Fig 1: Built-up area percentage versus distance from CBD for 2005 and 2020

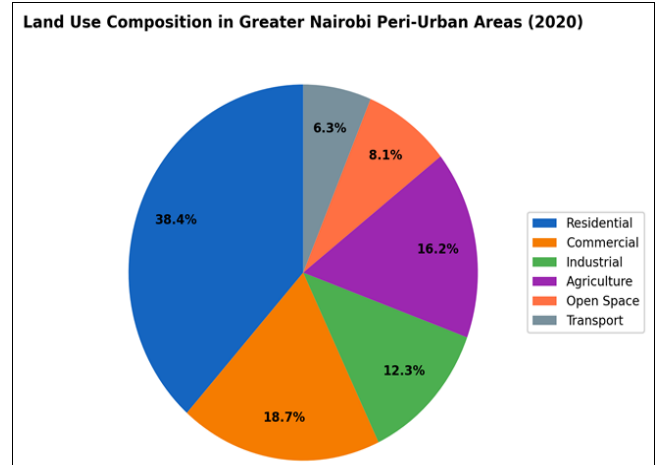


Fig 2: Land use composition in Greater Nairobi peri-urban areas (2020)

Comprehensive Interpretation

Built-up area expanded most dramatically in the 9–18 km and 18–27 km rings, gaining 28.7 and 27.4 percentage points respectively between 2000 and 2020 (Table 1, Figure 1). Residential development dominated new construction (38.4%), followed by commercial (18.7%) and industrial (12.3%) uses (Figure 2). The logistic model (pseudo- $R^2 = 0.73$) identified distance to nearest major road as the strongest single predictor of conversion (odds ratio 0.88 per km, $p < 0.001$), confirming corridor-driven sprawl (Table 2). Spatial clustering (Moran's $I = 0.74$) aligned with the Thika Superhighway and Mombasa Road corridors.

Discussion

The 187% built-up expansion between 2000 and 2020 exceeds rates reported for Kampala (143%)^[12] and Dar es Salaam (158%)^[13] over similar periods, making Nairobi one of the fastest-sprawling cities in East Africa. The corridor pattern—sprawl concentrated along highways rather than spreading uniformly—supports Mundia and Aniya's^[8] earlier observation that infrastructure investment catalyses conversion.

The peri-urban zone's 5.8% annual population growth, driven by residents priced out of inner Nairobi, creates a self-reinforcing cycle: new residents demand services, services attract commercial investment, and commercial investment raises land values further, pulling more agricultural land into conversion^[14, 15]. Breaking this cycle requires coordinated densification within the existing built-up area alongside strict enforcement of agricultural land protection zones.

Conclusion

Greater Nairobi's peri-urban sprawl is corridor-driven, concentrated along major highways, and consuming agricultural land at rates that current zoning regulations cannot contain. Distance to roads, CBD proximity, and land price are the strongest conversion predictors. Transport-oriented development that concentrates growth at transit nodes would be more effective than concentric containment. Without intervention, the 9–27 km ring will likely be fully urbanised within 15 years, permanently removing productive farmland from Kenya's highland agricultural zone.

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