

Spatial-Temporal Analysis of Human Settlement in Mwingi Central Sub-County from 1999-2025, Kenya

¹Florence Ndunge Kaloki, ²Julius M. Huho, ³Naftal Kariuki

¹Corresponding Author,

²Department of Arts and Social Sciences, Garissa University, P.O Box 1801-70100, Kenya,
School of Education

³Department of Mathematics and Natural Sciences, Garissa University, P.O Box 1801-70100, Kenya,
School of pure and applied Mathematics

Abstract: Human settlements in Kenya's arid and semi-arid lands (ASALs) have undergone significant spatial and temporal change driven by rapid population growth, rural-urban migration, infrastructure development, and environmental pressures. This study focused on Central Ward in Mwingi Central Sub-County, Kitui County, where unplanned settlement growth has progressively altered land use and land cover, degraded the environment, and strained public services. The study analysed spatial and temporal changes in human settlements between 1999 and 2025, examined drivers of those changes, assessed their effects on land use and land cover (LULC), and modelled future LULC changes to 2055. Central Place Theory guided the study. A cross-sectional research design was adopted, targeting 13,151 households, four chiefs, and the Sub-County Director of Planning. Using Cochran's formula, 373 households were sampled through simple random sampling. Key informants such as chiefs and the Director of Planning were purposively chosen. Primary data were collected through semi-structured questionnaires, observation checklists, and interviews. Secondary data comprised KNBS census reports. Quantitative data were analysed using IBM SPSS version 27. Findings revealed that total households increased by 80% from 7,311 in 1999 to 13,151 in 2019, with settlement growth decelerating from 4.2% per annum between 1999 and 2009 to 2.67% between 2009 and 2019. Growth was spatially uneven, concentrated in Mwingi and Kyanika sub-locations, while Enzui recorded negative growth. Clustered settlement patterns dominated Central Ward. The study recommends integrated land use planning.

Introduction

Human settlements around the world have been changing at a very fast rate as a result of population growth and pressure, technological development, and the growth of the global economy. Settlement dynamics include the patterns, distribution, and organization of human habitats, which have been changing significantly with the rapid shift from rural to urban environments in the past decades (United Nations, 2022). Towns and cities house more than half of the global population and are predicted to hit 68 percent of the world population by the year 2050. Urbanization is driven by rural-urban migration, which is a result of seeking jobs, advancement in infrastructure, and exposure to better social facilities like education and medical care.

The increasing urban sprawl and LULCC are due to technological advancement and infrastructural improvement, which have enhanced global connectivity (Chen *et al.*, 2020). Effects of human settlement changes are the expansion of agriculture, loss of vegetation cover, and conversion of agricultural and forest lands into residential, commercial, and industrial zones (Zhou *et al.*, 2019). To add on, depletion of agricultural land and urban sprawl are associated with expanding human settlements, biodiversity loss, and unsustainable resource exploitation (Henderson & Turner, 2020).

The changes in human settlement in Africa are also one of the quickest globally, and they are mainly caused by rural to urban migration and an increase in population. The urban population of Africa is expected to triple by 2050, which will create significant challenges in terms of sustainable land use and urban planning. Although migration and economic activities stimulate urban growth, much of Africa's urban expansion occurs informally, often outside planning frameworks or approved land-use and land-cover regulations. As a result, cities experience unplanned settlement growth, encroachment into agricultural lands, deforestation, and widespread environmental degradation. Technological development and infrastructure improvements have further contributed to expansion despite limited consideration for ecological sustainability.

In East Africa, rural-urban migration, population increase, and infrastructural expansion are the main variables influencing settlement change. Kenya, Tanzania, and Uganda have undergone the largest settlement growth in relation to improvements in transportation networks, energy distribution, and communication infrastructure. With technological development, settlements have also been able to expand to regions that have not been developed, which has driven greater penetration of markets and services and amplified land-cover

conversions. This high growth has led to the birth of agricultural land fragmentation, deforestation, and degradation of wetlands and forest reserves.

Human settlement in Kenya is no different, as both rural and urban areas are experiencing rapid development. Land-use change has increased rapidly in the country due to population growth, devolution, and an enormous infrastructural development. The population living in urban areas has grown intensely, whereas rural settlements have reached marginal territories and semi-arid regions. The main causes of this change are technological change, better infrastructure, economic diversity, and better social facilities that evolved as a result of devolution.

The settlement patterns in Kenya have transformed in the last twenty years. There is a rapid change in land use systems, particularly in arid and semi-arid counties like Kitui, due to the rapid population growth and urbanization (KNBS, 2019). The government has invested in roads, electrification, and good governance to create new settlements and economic areas. Nevertheless, slumming and spontaneous urbanization are occurring in more and more rural and agricultural areas. The changes have outpaced land use planning and environmental regulation, especially in low-income neighborhoods. Both natural increase and migration have led to population growth, which has further altered settlement patterns and increased land use in the regions around the trading centers.

Statement of Problem

Ideally, human settlement development should follow well-structured spatial and land-use planning and temporal frameworks guided by sustainable land use planning, effective policy implementation, environmental management, and efficient utilization of land resources. The inherent expectation is that this ensures that population growth, infrastructural development, and socio-economic activities occur in harmony with environmental conservation and service provision. However, in reality, human settlements in many parts of Africa, including Kenya, are expanding rapidly and often without proper planning. The situation in Mwingi Central sub-County mirrors this continental trend, where population growth, weak institutional capacity, infrastructural expansion, and livelihood activities have transformed traditional land use systems and land cover. These changes have resulted in uncoordinated settlement growth, uncontrolled urban sprawl, encroachment on agricultural land and degradation of natural ecosystems. Farmlands and rangelands are being converted into residential and commercial spaces, altering the natural landscape and threatening sustainable development. This study seeks to unearth the changes in human settlement that have taken place in Mwingi Central Sub-County between 1999 to 2025.

Objectives of the Study

The study's specific objective was to;

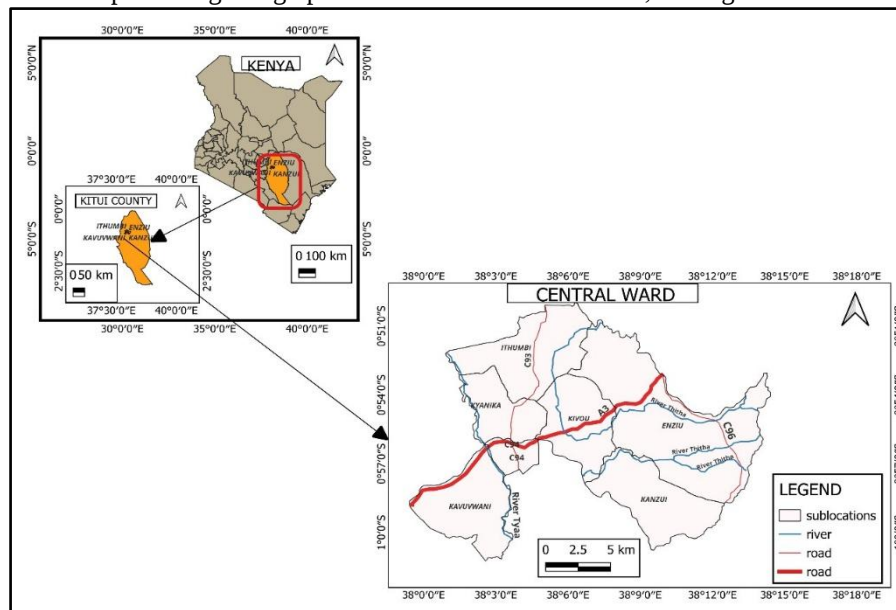
- To analyze spatial and temporal changes in human settlements in Mwingi Central Sub-County between 1999 and 2025.

Method and Materials

Description of the study area

The study was conducted in Mwingi Central Sub-County in Kitui County which consist of six wards namely; **Central, Kivou, Nguni, Nu, Mui, and Waita**. It covers an area of 1146 km². Its elevation ranges from 899 to 1126 m above sea level. It also lies in latitude 0°55'00"S and longitude 38°03'00"E with Mwingi Town serving as its main administrative and commercial center. In addition, the sub-county borders **Mwingi North Sub-County to the north, Mwingi West Sub-County to the west, Kitui East Sub-County to the south, and Tharaka-Nithi County to the east**. The study focused on the Central ward as it has both an urban and rural setup, thus giving a clear picture of how urban expansion and rural land use practices interact and influence changes in human settlements and land cover over time. Similarly, the ward lies in latitude 0° 56' 3.66" S and longitude 38° 3' 36.18" E, and it covers an area of 290 km². The Ward borders Kivou Ward to the north, Nguni Ward to the east, Waita Ward to the south, and Mui Ward to the west.

Figure 1: A map showing Geographical location of Central Ward, Mwingi Central Sub-County.



(Source ARCGIS (2025))

Study design

Cross-sectional survey integrated with retrospective geospatial analysis was used in the study due to its systematic way of documenting and analyzing the changes of human settlement in Mwingi Central Sub-County. The design was ideal as it enables collection of data at a single point in time to analyze the existing spatial patterns and trends of human settlement changes.

Limitation of the study

Household estimates of 2025 were not available therefore the data from satellite imageries was assumed to represent the estimates of 2025 (built-up areas).

Data Collection

Data was obtained from both primary and secondary sources. Primary data was gathered from questionnaires, interviews and observation checklist while secondary data was obtained from KNBS data and satellite imagery.

Primary Data

Primary data was collected using semi-structured questionnaires, observation checklists, and interviews. Semi-structured questionnaires and interviews were conducted to gather information on population demographics (Mwaura *et al.*, 2021). An observation checklist gave a record of visible features such as housing types and settlement structure thus providing complementary evidence to validate information gathered from questionnaires and interviews.

Secondary Data

Secondary data consisted of population data and land use and cover maps, which gave a glimpse of settlement dynamics changes. Population Data was sourced from reports of the KNBS of 1999, 2009 and 2019.

Data Analysis and Presentation

Verbatim analysis was used to analyze the qualitative data. The qualitative data from (KIIs) was transcribed, coded, and triangulated with quantitative findings in order to emphasize the community views and professional opinion on the settlement changes. Data from open-ended questionnaires was cleaned to remove errors. Repeated themes were identified and codes assigned to responses that correspond to the themes.

Quantitative data from questionnaires was analyzed to determine descriptive and inferential statistics such as frequencies, means, and standard deviation using SPSS software version 27.

Numerical data such as household figures and percentage changes in settlement was organized in spreadsheet and finally presented in form of tables and percentages. Observation check list recorded visible

physical features and environmental characteristics such as housing types, settlement types, infrastructure distribution, vegetation cover to validate data collected through questionnaires and interviews.

Results and Discussion

The study administered 373 questionnaires to households' heads in Central Ward. A total of 343 questionnaires from 373 were returned. However, out of the 343 returned, 310 questionnaires were reasonably and adequately completed representing approximately 83 % out of the targeted population. The responses provided enough data for analysis as Robert et al., (2020) observes that response rate exceeding 80% is ideal for analysis. Key informant interviews were conducted with relevant stakeholders, achieving an 100% response rate.

Spatial and Temporal Changes in Human Settlements

The first objective sought to analyze spatial and temporal changes in human settlements in Mwingi Central Sub-County between 1999 and 2025. To achieve this, KNBS data of 1999, 2009, 2019 on households and population size and observation checklist was analyzed alongside respondents' views on observed settlement changes. To determine the changes in human settlement, the study analyzed the number of households, population size and density, remote sensing images showing settlement patterns and mapping settlement changes using GIS from 1999 to 2025. The spatial and temporal changes in human settlements were computed, and the findings are presented in Table 14.

Table 1: Spatial and temporal changes in human settlement descriptive statistics

	SD	D	A	SA	n	Mean	Std. Dev.
There has been an increase in the size of settlements in this area from 1999-2025.	15	17	219	59	310	3.04	.662
Settlement growth in this area have been evenly distributed from 1999-2025.	40	198	57	15	310	2.15	.696
There has been a noticeable increase in population density within existing settlements from 1999-2025.	13	16	259	22	310	2.94	.536

(Field Survey, 2025)

The descriptive findings revealed spatial and temporal changes of human settlement had occurred in Central Ward between 1999 and 2025. These findings suggested that settlement growth has occurred both through the physical expansion of settlements and through the concentration of people within already established settlements (figure 5). The observation aligned with UN-Habitat (2022) who found that in developing countries, urban population growth continues to push the expansion of cities outward and the increased density of existing urban areas as people gravitate to carry economic activities in urban and peri-urban areas.

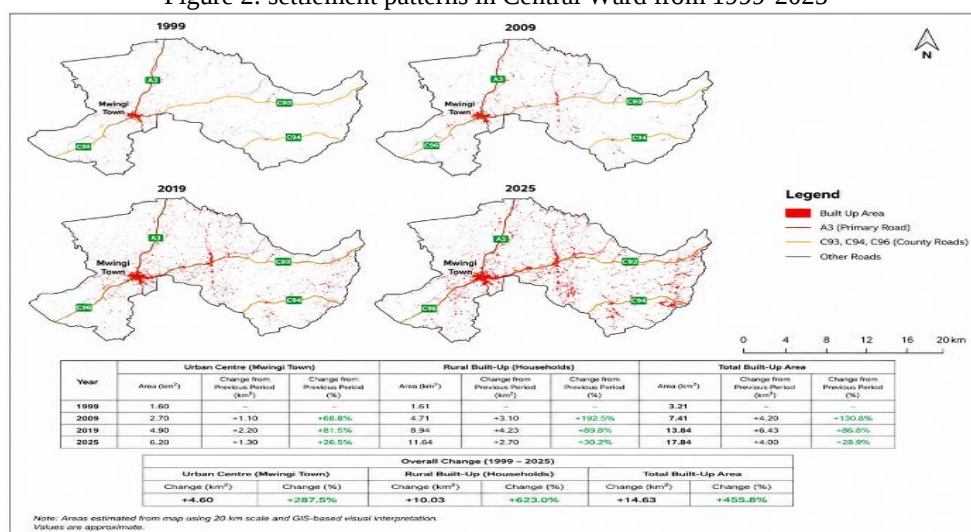
The findings further indicated that settlement growth had not been even across the study area as 76.8% (238) of the respondents indicated that there was no uniform growth of settlements. This was supplemented by the secondary data of households and population distribution across sublocations (table 15), which showed that settlement growth was very high in Mwingi and Kyanika sub-locations compared to other sub-locations like Enzui due to differences in access, availability of infrastructure, access to markets and administration. The OECD, United Nations Economic Commission for Africa, & African Development Bank. (2022) reported the same, noting that population and economic activities were more likely to be clustered in well-connected urban and peri-urban centres, resulting in spatial inequalities in development and service provision.

Increased population density was also reported by respondents 90.6% (281), which also indicated increased pressure on land resources. With rising population, households were compelled to settle in smaller land units, which led to increase in settlement density. This aligned with UN-Habitat (2022) which suggested that urban population growth increasingly takes place not only through expansion but also through densification Moreso in economically active centres where the need for housing and services is high, density increases is noticeable.

Spatial Changes of Human Settlement

The spatial changes of human settlement were analyzed using Satellite imagery which provided settlement pattern maps and areas coverage of built-up areas. The settlement pattern was analysed using satellite images of 1999, 2009, 2019 and 2025. They were classified as built -up areas to indicate the spatial extend of settlement patterns (figure 5).

Figure 2: settlement patterns in Central Ward from 1999-2025



Adopted from QGIS, USGC, Copernicus Hub

The settlement maps demonstrate that Central Ward experienced substantial spatial transformation between 1999 and 2025. Initially, settlements were concentrated around Mwingi Town (Fig 5-year 2019) but over time they expanded along the major road network (Fig 5-year 2025). The dominant settlement forms observed include nucleated, linear and dispersed settlements, indicating progressive urban expansion and peri-urbanization. In 1999, settlements were predominantly clustered around the main urban centre of Mwingi Town, with only a few scattered homesteads distributed across the rural landscape. Peripheral sub-location such as Enzui, remained largely sparsely settled, indicating limited development and lower population pressure. In Mwingi Town, the urban centre occupied about 1.60 km², while rural built-up areas occupied 1.61 km², resulting in a total built-up area of 3.21 km². The settlement pattern was predominantly nucleated, where residential, commercial and institutional developments clustered around the Mwingi Town centre. This concentration reflected the role of Mwingi Town as the administrative and commercial centre providing employment, markets, education, healthcare, and transport services. Such a pattern is consistent with Christaller's Central Place Theory, which explains that settlements initially concentrate around centres offering higher-order services before gradually expanding into surrounding areas (Christaller, 1933).

Between 1999 and 2009, settlements expanded rapidly along the A3 highway and County Roads C93, C94, and C96, producing a distinct linear settlement pattern (Figure 5). During this period, the urban centre built up area increased by 68.8%, while rural built-up areas expanded by 192.5%. This indicated that rural residential development occurred more rapidly than urban growth. This demonstrates the importance of transport infrastructure in directing settlement expansion. A similar observation was made by Rotich and Opiyo (2022), who found that urban growth in Eldoret Municipality occurred predominantly along the Nairobi–Uganda highway and other major roads, creating linear settlement patterns because accessibility encourages residential, commercial, and institutional development. The GIS-based analysis further revealed that road networks strongly determine the spatial direction of urban expansion.

By 2019, settlement development had evolved into a combination of linear and dispersed settlement patterns. Although the highest concentrations of built-up areas remained along the transport corridors, many new homesteads appeared further into the rural hinterland. Rural built-up areas increased from 4.71 km² to 8.94 km², while the total built-up area reached 13.84 km². Interviews with chiefs indicated increasing subdivision of agricultural land for residential purposes and the gradual emergence of peri-urban settlements such as Kisama and kavuoni. Similar findings were reported by Nyongesa et al. (2022) in Voi Town, who observed that rapid urban growth resulted in the outward expansion of built-up areas into agricultural land, creating low-density residential developments and dispersed settlement patterns around the urban fringe.

The 2025 map indicated a more advanced stage of settlement expansion characterized by extensive urban sprawl. The urban centre expanded to 6.20 km², while rural built-up areas reached 11.64 km², producing a total built-up area of 17.84 km². Compared with 1999, the urban centre increased by 287.5%, rural built-up areas by 623.0%, and the total built-up area by 455.8%. Three dominant settlement forms are evident: compact nucleated settlements around Mwingi Town, linear settlements along the A3, C93, C94, and C96 roads, and dispersed settlements throughout the rural hinterland. These patterns indicate increasing peri-urbanization driven by

population growth, improved accessibility, housing demand and infrastructure development (Khanani et al. 2021)

Overall, the settlement evolution in Central Ward followed a systematic progression from nucleated settlements (1999) to linear development along major roads (2009), followed by mixed linear and dispersed settlements (2019) and finally extensive urban sprawl and peri-urban expansion (2025). The maps clearly demonstrated that road accessibility, population growth, and increasing demand for residential land have been the primary drivers of settlement expansion.

Settlement growth in Central Ward was analysed using classified satellite imagery by extracting the built-up land cover class for the years 1999, 2009, 2019, and 2025 (figure 5). The analysis revealed a sustained a significant increase in built-up area throughout the study period, indicating continuous expansion of human settlements within the ward. The built-up area increased from 3.21 km² in 1999 to 7.41 km² in 2009, representing an increase of 4.20 km² (table 16).

Table 2: built up area coverage statistics from 1999-2025 in km²

LULC	1999	2009	Change	2019	change	2025	Change	TOTAL
Built-up areas	3.21	7.41	4.2	13.84	6.43	17.84	4	41.96

Between 2009 and 2019, the built-up area further increased to 13.84 km², recording an additional 6.43 km², while between 2019 and 2025 it expanded to 17.84 km², representing a further increase of 4.00 km². Overall, the ward experienced substantial growth in built-up land of 41.96 km², demonstrated continuous settlement expansion during the study period.

The steady increase in built-up area indicated that Central Ward has experienced sustained urban growth over the last twenty-six years. The greatest increase occurred between 2009 and 2019, when built-up areas increased by 6.63 km². The County Director Planning attributed this substantial expansion was to the combined effects of population growth, Mwingi Town's growing role as a commercial and administrative centre, and improved accessibility associated with its location along the A3 Nairobi–Garissa highway and connecting roads such as C93 and C94. This finding agrees with Annan et al. (2022), who found that the rapid population growth of Nakuru Town resulted in significant expansion of built-up areas, with agricultural and open spaces increasingly converted into residential, commercial, and public land uses to accommodate urban growth. Fekete (2023), also reported that the rapid expansion of Nairobi and Nyeri had transformed peri-urban landscapes through continuous growth of the built environment into previously undeveloped land, increasing land-use conversion and urban sprawl.

The relatively lower increase in settlement coverage between 2019 and 2025 (4 km²) was attributed to the shorter observation period of six years, compared with the ten-year period between 2009 and 2019; therefore, the magnitude of change across the two periods was interpreted with consideration of their unequal durations. This pattern suggests the gradual consolidation of existing settlements as available land for outward expansion becomes increasingly limited, a trend also affirmed by the chiefs. Comparable trends have been reported in Eldoret Municipality, where built-up areas expanded consistently over time while vegetation and agricultural land declined because of continued urban development. Rotich & Opiyo (2022) attributed these changes to increasing demand for housing, commercial facilities, and supporting infrastructure associated with rapid urbanization.

Overall, the substantial increase in built-up land confirms that Central Ward has undergone significant settlement growth during the study period. The observed expansion reflects increasing urbanization, population concentration, and socio-economic development that have transformed the spatial organization of the ward. Similar findings were reported in the peri-urban areas of Nakuru City, where land-use analysis between 2003 and 2023 revealed continuous growth of built-up land at the expense of shrubland and other natural land-cover classes as the city expanded into surrounding areas (Cherotich et al., 2024). These findings demonstrated that the settlement growth observed in Central Ward follows the broader pattern of urban expansion occurring in Kenya's emerging urban centres.

Temporal changes of Human Settlements

Temporal changes in human settlements were analyzed based on settlement size and distribution, using growth rates and household intensity in Central Ward. Household data from the KNBS data 1999, 2009 and 2019 was used. The number of households informed how settlements grow and expand over time. The population and the numbers of households in Central Ward increased steadily from 1999 to 2019 (Table 16).

Table 3: Household density in the Central Ward

Sub-location	1999			2009			2019		
	Household	Area	Intensity	Household	AREA	Intensity	Household	AREA	Intensity
Enzui	1021	98.7	10.41	1311	98.08	13.27	1049	63.9	16.42
Kanzui	348	39.8	8.74	432	39.61	10.91	571	38.5	14.83
kavuoni	-	-	-	-	-	-	525	16.5	31.82
Kavuvwani	765	39.5	19.37	913	39.51	23.10	645	22.5	28.67
Mwingi	2746	9	305.11	3924	9.25	424.21	4820	9.1	529.67
Kivou	608	34.2	17.78	785	33.85	23.19	604	39.8	15.18
kisama	-	-	-	-	-	-	976	30.3	32.21
Ithumbi	590	45.8	12.88	850	47.02	18.08	1028	47.4	21.69
Kyanika	1233	24.4	50.5	2165	24.36	87.83	2933	22.0	133.32
TOTAL	7311	291.68	25.07	10380	291.68	35.24	13,151	290	45.35

(KNBS 2019,2009,1999)

The number of households had grown considerably in the study period, with the total number increasing from 7,311 in 1999 to 13,151 in 2019 and the population increased from 31,982 in 1999 to 47,353 in 2019 (table 15). Overall, the findings indicated a substantial increase in household intensity during the study period. The overall household intensity increased from 25.07 households/km² in 1999 to 35.24 households/km² in 2009, before reaching 45.35 households/km² in 2019, representing an increase of approximately 81% over the two decades.

Among the sub-locations, Mwingi consistently recorded the highest household intensity, increasing from 305.11 households/km² in 1999 to 424.21 households/km² in 2009 and 529.67 households/km² in 2019. As the administrative and commercial centre of Mwingi Central Sub-County, Mwingi attracted population through employment opportunities, business activities, access to markets, educational institutions, health facilities and transport infrastructure. These findings are consistent with recent studies that report urban and peri-urban centres in Kenya continue to experience increasing household concentration driven by infrastructure development and economic opportunities .

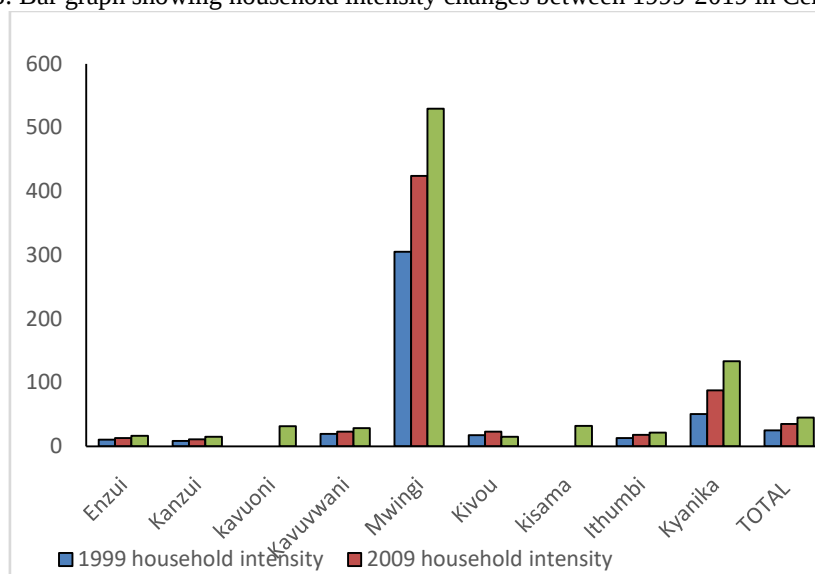
Kyanika also exhibited a remarkable increase in household intensity from 50.50 households/km² in 1999 to 87.83 households/km² in 2009 and 133.32 households/km² in 2019, indicating sustained settlement expansion. Likewise, Kavuoni, which appears as a separate administrative unit in the 2019 data, recorded a household intensity of 31.82 households/km², while Kisama recorded 32.21 households/km². Their emergence reflected administrative subdivision associated with population growth and increasing settlement density.

Other sub-locations also experienced notable increases in household intensity. Ithumbi increased steadily from 12.88 to 18.08 and 21.69 households/km², while Kanzui rose from 8.74 to 10.91 and 14.83 households/km². This gradual increase suggested continued household formation and moderate settlement expansion without the rapid urbanization observed in Mwingi. Similar patterns have been observed in semi-arid counties of eastern Kenya, where household growth is largely driven by natural population increase and gradual rural settlement expansion rather than rapid urban development.

Enzui increased from 10.41 households/km² in 1999 to 13.27 households/km² in 2009, but later rose further to 16.42 households/km² in 2019. Conversely, some sub-locations recorded declining household intensity despite population growth during earlier years. Similarly, Kavuvwani showed continuous growth from 19.37 to 23.10 and 28.67 households/km², although its household numbers declined by 2019 because part of its area and households were redistributed following boundary adjustments. These patterns demonstrated that administrative restructuring influence household intensity independently of demographic change.

Kivou presented a contrasting pattern. Household intensity increased from 17.78 households/km² in 1999 to 23.19 households/km² in 2009, before declining to 15.18 households/km² in 2019 (figure 6). The decline resulted from both a reduction in household numbers and an increase in the recorded land area, from 33.85 km² to 39.8 km² suggesting redistribution of settlements and changes in administrative boundaries following the promulgation of the Constitution of Kenya on August 27, 2010 as the IEBC adjusted administrative boundaries (IEBC 2012) rather than simple population decline.

Figure 3: Bar graph showing household intensity changes between 1999-2019 in Central ward



A Friedman test was conducted to determine whether the number of households differed significantly across the three census years (1999, 2009, and 2019) among the seven sub-locations of Central Ward. The results showed a statistically significant difference in household intensity across the three periods, $\chi^2 (2) = 12.286$, $p = 0.002$. This finding indicated that household intensity changed significantly between 1999 and 2019.

The number of households increased from 7,311 in 1999 to 10,380 in 2009 and further to 13,151 in 2019. This represented an overall increase of 5,840 households, equivalent to approximately 79.9%, over the 20-year period (table 16). The rate of household growth was 4.2% between 1999 and 2009, but declined to 2.67% between 2009 and 2019. At the same time, household intensity increased from 25.07 in 1999 to 35.24 in 2009 and 45.35 in 2019, indicating an increasing concentration or intensity of households within the study area. The decline in household growth rate alongside increasing household intensity suggests settlement densification and consolidation rather than a reversal of settlement growth.

Using the following formula, population growth rates for the periods 1999-2019 were established.

$$h = \frac{hf - hi}{hi} \dots \dots \dots (1)$$

$$r = \frac{h}{t} * 100 \dots \dots \dots (2)$$

hf -the final number of households

Hi-initial number of households

H-the difference between the final and initial number of households

r-rate of growth

t-time in years

From the formula the following growth rates were established (table 17)

Table 4: Rate of household Growth in 1999, 2009 and 2019

YEAR	No of households	Rate of growth	Household Intensity
1999	7311	-	25.07
2009	10380	4.2	35.24
2019	13,151	2.67	45.35
TOTAL	30,842		

(Adapted from KNBS 1999,2009 and 2019)

The sharp increase in households between 1999 and 2009 suggested that Central Ward experienced substantial population and settlement growth during the first decade. The increase from 7,311 to 10,380 households represented an addition of 3,069 households which is 42.0%. As the urban centre attracted economic activities, employment opportunities, markets and social services, households increasingly settled within accessible peripheral areas of the ward. The relatively high growth rate of 4.2% therefore indicated a period of relatively rapid household formation and settlement expansion. This finding was consistent with the Kitui

County Integrated Development Plan (2023–2027), which identified Mwingi Central as an important urban and economic centre and provided for the expansion of markets, roads, drainage, street lighting and other infrastructure within Mwingi Municipality. The plan's emphasis on improving infrastructure and commercial facilities supported the observed relationship between the growing importance of Mwingi Town and increasing settlement development in its surrounding areas.

Between 2009 and 2019, although the absolute number of households increased, the growth rate declined from 4.2% to 2.67%. This suggested that settlement growth remained positive but occurred at a slower rate than during the preceding decade. The decline did not necessarily indicate a reduction in settlement development; rather, it suggested that the rate of household increase had moderated after the rapid growth experienced between 1999 and 2009. This continued growth was consistent with recent development evidence from Mwingi Central, where the Kitui County Annual Development Plan 2024/2025 reported that road improvements in Central Ward intended to enhance mobility and commercial activities within Mwingi Town and its environs. The same plan also reported street-lighting improvements in Central Ward, demonstrating continued infrastructure development within the area.

The declining growth rate suggested a transition from rapid expansion to a slower, more stabilized phase of settlement development. This pattern aligns with global urbanization trends where growth initially accelerates and later slowed due to land constraints, infrastructural limitations, and economic adjustments (Tang et al., 2024). In many developing regions, early phases of settlement growth are characterized by rapid outward expansion, followed by a phase of densification and consolidation as available land becomes limited (Yu et al., 2023).

The variation in household growth across sub-locations reflected differences in accessibility, economic opportunities, and land availability. Between 1999 and 2009, Kyanika (7.56%) and Ithumbi (4.41%) recorded the highest households growth rate, indicating rapid settlement expansion in these areas (Table 17). In contrast, Kavuvwani (1.94%) had the lowest household growth rate. Between 2009 and 2019, Kivou recorded the highest household growth rate (10.13%). However, Enzui recorded a negative growth rate (-2.00%), indicating a decline in household growth. Rapidly growing areas such as Kivou and Kyanika were benefiting from proximity to Mwingi Sublocation which is a commercial hub and had improved connectivity, which attract population and investment. This agrees with the findings of Güneralp et al. (2020) who reported that settlement growth in developing regions is often concentrated in urban and peri-urban nodes due to economic and infrastructural advantages. Similar patterns have been observed globally, where settlement growth is clustered in favorable locations, creating regional inequalities (Tang et al., 2024).

Table 5: Rate of household Growth in Central Ward Sub-location

Sub-location	1999 households	2009 household	Rate of growth (1999-2009) %	2019 households	Rate of growth (2009-2019) %
Enzui	1021	1311	2.84	1049	-2.00
Kanzui	348	432	2.41	571	3.22
Kavuvwani	765	913	1.94	1170	2.81
Mwingi	2746	3924	4.29	4820	2.28
Kivou	608	785	2.91	1580	10.13
Ithumbi	590	850	4.41	1028	2.09
Kyanika	1233	2165	7.56	2933	3.55
TOTAL	7311	10380	4.2	13,151	2.67

(Adopted from KNBS 2019,2009,1999)

Between 1999 and 2009 Enzui recorded a decline. Chief of the area reported that the Sub-location was affected by recurrent flooding along the Enzui River which significantly influenced population distribution and settlement patterns by discouraging permanent occupation of flood-prone areas, causing temporary displacement during extreme rainfall events. Overall, Table 18 indicates uneven settlement expansion, with some areas experiencing accelerated growth while others stagnate or decline. Interview with chiefs confirmed the household growth rates.

Discussion of Findings

According to this study results human settlements in Central Ward experienced substantial spatial and temporal expansion between 1999 and 2025. Primary data showed that 70.6% of respondents agreed and 19.0% strongly agreed that the size of settlements had increased during the study period, with a mean of 3.04 and standard deviation of 0.662. Similarly, 90.6% of respondents reported a noticeable increase in population density within existing settlements, with a mean of 2.94 and standard deviation of 0.536. These findings

demonstrate that settlement change occurred through both outward physical expansion and increasing concentration of people within existing settlements.

The spatial analysis of satellite imagery confirmed a continuous expansion of built-up areas. Built-up land increased from 3.21 km² in 1999 to 7.41 km² in 2009, 13.84 km² in 2019 and 17.84 km² in 2025. This represented successive increases of 4.20 km² between 1999 and 2009, 6.43 km² between 2009 and 2019, and 4.00 km² between 2019 and 2025. The results therefore demonstrated sustained settlement expansion throughout the 26-year period. The greatest increase occurred between 2009 and 2019, indicating that this decade experienced particularly rapid residential, commercial and institutional development.

The spatial pattern of settlement development also changed progressively over time. In 1999, settlements were predominantly nucleated or clustered around Mwingi Town, with limited development in the rural hinterland. The urban centre covered approximately 1.60 km², while rural built-up areas occupied 1.61 km², giving a total built-up area of 3.21 km². By 2009, settlement expansion had increasingly followed the A3 highway and C93, C94 and C96 roads, producing a distinct linear or ribbon pattern. By 2019, the settlement pattern had evolved into a combination of linear and dispersed development as new homesteads spread further into the rural hinterland. In 2025, the area exhibited extensive peri-urban expansion and urban sprawl, characterized by three dominant forms: compact nucleated settlements around Mwingi Town, ribbon development along major roads, and dispersed settlements across the rural hinterland.

The findings further demonstrated that settlement growth was spatially uneven. A total of 76.8% of respondents indicated that settlement growth had not been uniformly distributed across the study area. Secondary data supported this observation, showing that Mwingi and Kyanika experienced considerably greater settlement concentration and growth than peripheral areas such as Enzui. Mwingi remained the principal settlement concentration because of its role as an administrative, commercial and service centre, while Kyanika experienced strong peri-urban growth. The concentration of settlements around Mwingi was associated with accessibility, employment opportunities, markets, educational institutions, health facilities, financial services and administrative functions.

Temporal analysis of household numbers provided further evidence of sustained settlement growth. The total number of households in Central Ward increased from 7,311 in 1999 to 10,380 in 2009 and 13,151 in 2019, representing an overall increase of 5,840 households, equivalent to approximately 79.9% over the 20-year period. The household growth rate was 4.2% between 1999 and 2009, before declining to 2.67% between 2009 and 2019. Thus, although settlement growth remained positive throughout the period, its rate moderated during the second decade. The decline in growth rate was interpreted as a transition from rapid outward expansion towards slower growth, consolidation and increasing concentration within already developed areas.

The household intensity analysis reinforced the evidence of increasing settlement concentration. Overall household intensity increased from 25.07 households/km² in 1999 to 35.24 households/km² in 2009 and 45.35 households/km² in 2019, representing an increase of approximately 81% over the two decades. Mwingi recorded the highest household intensity, increasing from 305.11 households/km² in 1999 to 424.21 households/km² in 2009 and 529.67 households/km² in 2019. Kyanika also recorded substantial increases, from 50.50 households/km² in 1999 to 87.83 households/km² in 2009 and 133.32 households/km² in 2019. These patterns indicated increasing concentration of households within areas with better accessibility, infrastructure, markets and economic opportunities.

At the sub-location level, settlement growth varied considerably. Between 1999 and 2009, Kyanika recorded the highest household growth rate at 7.56%, followed by Ithumbi at 4.41%, while Kavuvwani recorded the lowest at 1.94%. Between 2009 and 2019, Kivou recorded the highest growth rate at 10.13%, whereas Enzui recorded a negative growth rate of -2.00%. The negative growth in Enzui was associated with recurrent flooding along the Enzui River, which discouraged permanent occupation of flood-prone areas and contributed to temporary displacement during extreme rainfall events. These variations demonstrate that settlement growth was strongly differentiated by local environmental conditions, accessibility, infrastructure and economic opportunities.

The statistical analysis confirmed that the observed temporal and spatial variations were significant.

Overall, the findings demonstrated that human settlements in Mwingi Central Sub-County, particularly Central Ward, underwent substantial spatial and temporal transformation between 1999 and 2025. The transformation was characterized by continuous expansion of built-up areas, increasing household numbers and intensity, rising population concentration, uneven spatial growth, and progressive changes in settlement morphology. Settlement development evolved from compact nucleated settlements around Mwingi Town in 1999, to linear/ribbon development along major roads in 2009, mixed linear and dispersed development in 2019, and extensive urban sprawl and peri-urban expansion by 2025. The findings therefore confirm that settlement growth in the study area was not uniform but was concentrated around the urban centre, transport corridors and areas with greater access to infrastructure, services and economic opportunities.

Conclusion

There was important spatial and temporal change in the human settlement in Mwingi Central Sub-County from 1999 to 2025 measured in both the extent and the distribution of settlement. There was a measurable spatial and temporal change in human settlements in Mwingi Central Sub-County from 1999 to 2025 in terms of extent and distribution of settlement. The total number of households grew from 7,311 in 1999 to 13,151 in 2019, an 80% increase, while the population rose from 31,982 to 47,353 over the same period. Between 1999 and 2009 the rate of settlement growth was 4.2% per annum but this slows to 2.67% per annum in the period 2009 to 2019, reflecting a transition from rapid expansion outwards to a period of densification and stabilisation, as available land became more limited. The results of the settlement expansion are therefore uneven, with positive settlement expansion on the most economically and infrastructurally favourable sub-locations like Mwingi and Kyanika, and negative growth rates on the less economically and infrastructurally endowed sub-locations like Enzui, thus demonstrating the spatial inequalities that shape the geography of settlement development in the sub-county. The clustered and dispersed settlement patterns across the ward were prevalent respectively at the service centres and transport corridors in the ward, and the agricultural and pastoral sub-locations. The population density rose significantly, and population pressure was taken up in-situ by adding onto existing settlements as well as outward by building new ones. This result is consistent with Corbane et al. (2021) who documented built-up area expansion across all sub-Saharan African urban and peri-urban contexts driven by demographic growth.

Recommendation

Based on the study findings and conclusions, the study recommends Strengthening Integrated Land Use Planning and Zoning in Mwingi Central Sub-County. The study findings confirmed that settlement expansion has been spatially uneven and largely unguided, resulting in encroachment on natural vegetation, marginal agricultural land, and ecologically sensitive areas. It is therefore recommended that the Kitui County Government, through the Department of Physical Planning, develops and enforces a comprehensive Integrated Land Use Plan for Central Ward that designates clear zones for residential, commercial, agricultural, conservation, and infrastructure uses. This plan should be reviewed every five years to reflect population growth. This is in line with Maina and Waiganjo (2024), who confirmed that the absence of coordinated land use planning is the primary institutional driver of informal and uncontrolled settlement expansion in peri-urban East African contexts.

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