

Spatial Characterization of Peri-Urban Neighborhoods Generated by Parcel-Based Planning and Development in Satellite Towns South of Nairobi Metropolitan, Kenya

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Abstract: Peri-urbanization in African countries is often characterized by fragmented and poorly coordinated land-use planning and development, raising concerns regarding the liveability and sustainability of emerging peri-urban neighbourhoods. This study examines spatial characteristics of neighbourhoods created through ad hoc sporadic parcel-based land use planning practices of preparing land subdivision layout plans without an existing comprehensive land use plan that guides the neighbourhood development. The study seeks to establish how ad hoc parcel-based land use planning, subdivision, and development influence liveability and sustainability spatial characteristics of peri-urban neighbourhoods. Three neighbourhood liveability and sustainability spatial parameters; land use mix, proximity and density of neighbourhoods are evaluated in three neighbourhoods in peri-urban areas South of Nairobi Metropolitan area—Kitengela, Athi River and Ongata Rongai using spatial data from Registry Index Maps (RIMs), cadastral survey plans, land use plans, Google Images and OpenStreetMaps. The results reveal contrasting aggregated land-use allocations, with Athi River locality predominantly allocated to industrial (65.86%), residential (17.41%), and transportation (13.60%) uses; Kitengela to residential (58.53%), commercial (14.88%), transportation (14.44%), public-purpose (5.95%), and industrial (4.70%) uses; and Ongata Rongai to residential (92.18%) and transportation (7.82%) uses, with other uses accounting for less than 1% or 0% of land allocation. These findings demonstrate that ad hoc sporadic piecemeal parcel-based land use planning, subdivision and development prioritize creation of living (residential land use) and working (industrial and commercial use) spaces with limited provision of social spaces which improve quality of life, human well-being, and social development such education, health and safety, recreation, and governance facilities. This results in very low land use mix, mixed-up residential densities and limited accessibility. Reactionary piecemeal parcel-based land use planning, subdivision and development triggered by immediate development needs creates peri-urban neighbourhoods with low spatial liveability and sustainability characteristics. These findings highlight the need to adopt a digital parcel-based land use planning and subdivision approval system that assesses and integrates spatial planning requirements to aid in subdivision plan approval decision making in order to enhance neighbourhood liveability and sustainability.

Keywords: land use allocation; land use mix; entropy; density; parcel-based planning



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1. Introduction

Rapid urbanization in Africa is attributed to natural increase in population, rural-urban migration, spatial expansion and reclassification of rural settlements [1–4]. It is projected that Africa will experience the fastest urban growth worldwide in the coming decades and land area occupied by cities will triple by 2030, resulting in wasteful consumption of land [3,5]. Adu-Gyamfi [6] observed that peri-urban communities develop naturally and spontaneously without appropriate spatial arrangements. Therefore, peri-urban areas are transition zones where urban and rural activities interweave and the physical environment is subjected to rapid transformation as a result of human activities [7–10].

Peri-urban developments in developing countries are characterized by unplanned or poorly planned land use resulting in social, environmental, economic and health inequities [8,11,12]. The literature points to a high degree of fragmentation of land use and management in peri-urbanization [13–15]. Legates & Hudalah, [16] posit that considerable amount of spatial and land use planning takes place in peri-urban albeit in fragmented manner among types of plans. Spatial and land use planning can protect lands of agricultural significance from urban and peri-urban encroachment and ensure that land use reflects land capability or land suitability [17].

Comprehensive land use planning approaches, particularly master planning and neighbourhood planning are notable methods used to allocate competing land uses and to influence orderly development in neighbourhoods, municipalities, cities or any defined planning area [17]. In the absence of comprehensive plans to guide urban development expansion, planners have adopted ad hoc, piecemeal or parcel-based planning to provide minimum planning solutions amid rapid urbanization and proliferation of informal settlements [18–21]. This fragmented planning lacks the holistic view that is present in comprehensive planning approaches like master planning [22,23]. Peri-urbanization is taking place through this fragmented planning approach creating neighborhoods through conglomeration of parcel-based land use plans. Existing research has examined fragmented planning and development practices at the peri-urban scale, peri-urban land-use change dynamics using satellite imageries, drivers of fragmented land use planning in peri-urbanization, computational parcel-level and cellular automata land use allocation models, and individual planning conformance to local land-use policies [24–29]. However, previous research has not sufficiently focused on characteristics of neighbourhoods (neighbourhood-scale outcomes) generated by cumulative aggregation of fragmented parcel-based land use planning and developments.

Land use planning and development control in developing countries—especially in sub-Saharan Africa—have been hindered by a lack of planning tools and equipment, lack of central government commitment, weak enforcement of planning regulations, low capacity of local planning authorities, inadequacy of professionally qualified planners, ineffective development control procedure, lack of public participation, and informal land tenure system [18,22,30,31]. These hindrances to land use planning have resulted in existence of either unplanned developments or ad hoc sporadic planning, which is a reactionary planning triggered by immediate development needs that results in micro layout plans to cater for development initiatives like housing [18]. Therefore, this study examines spatial characteristics—land use mix, proximity and density—of neighbourhoods created by conglomeration of fragmented land-use planning, subdivision and development of different land parcels of rural land into urban plots without an existing comprehensive plan in peri-urban areas south of Nairobi Metropolitan.

2. Theoretical Framework

This article examines spatial characteristics of neighbourhoods generated from ad hoc parcel-based land use planning of peripheries of satellite towns. Theories and models addressing peri-urbanization and neighbourhood planning are significant to this study. Peri-urbanization theory provides basic theoretical foundation for interpretation of spatial consequences of urban expansion. Peri-urbanization describes the transformation of rural areas on the peripheries of established cities to adopt urban social, physical and economic attributes [32]. Urban peripheries of the Global South are experiencing the most dynamic urbanization process in the contemporary world [33]. Satellite towns are planned or emerging urban settlements designed to manage and contain urban sprawl from an adjacent prime city [34]. The theories promoting creation of better and liveable neighbourhood characteristics have been developed since early 20th century [35]. Neighbourhood liveability and sustainability spatial characteristics are backed by theories and principles inter alia Ebenezer Howard's Garden City, the Clarence Perry's concepts of Neighbourhood Unit, Compact city, New Urbanism, Transit Oriented Development, Smart Growth, Eco-Urbanism and 15-min city [35–38].

In the beginning of the 20th century, the Ebenezer Howard's Garden City [39] concepts had sought controlled integration of city and countryside through poly-nucleated self-sustaining low density settlements consisting of concentric patterns with public spaces and parks [35,40–42]. Howard proposed a series of zoned areas for housing, recreation and work separated by green belts [43]. The Howard's Garden City concept introduced self-contained

communities surrounded by greenbelts and containing proportionate areas of residence, industry, and agriculture with emphasis on commercial and employment activities located near major thoroughfares [38,44]. The garden city movement is considered as the origination of the satellite city and the new town concept [45–47].

The Howard's Garden City attributes such as ample green space, street patterns and single family residential units are still pertinent in suburban developments. Even though it embraced segregation of land uses (zoning) [35,43] instead of land use mix, density was critical in the Garden City theory. Howard proposed low density of 30,000–32,000 inhabitants in an area of 6000 acres [38–40,44,48]. The Clarence Perry's concepts of Neighbourhood Unit proposed in 1923 required design of self-sufficient neighbourhood with all the public facilities and conditions required by an average family's comfort and proper development within the vicinity of its dwelling [49]. Clarence Perry in the Neighbourhood Unit identified six basic principles of neighbourhood design as: a fixed residential unit area based on an elementary school service area within a one quarter mile (400 m) walking distance, the unit boundaries should be sufficiently wide arterial streets on all sides to facilitate efficient bypassing traffic, a system of small parks and recreational spaces, interior street patterns designed to facilitate circulation within the unit but deter through traffic, institutional site at neighborhood focal point with elementary school and other service institutions, and shopping district situated at the edge of neighbourhoods preferably at major street intersections [50–52]. According to Perry, the Neighbourhood Unit should comprise an area of 160 acres (65 ha) with a neighbourhood population size of between 5000 and 6000 inhabitants [50,52] implying a low population density of 10 families per acre [50], population density of 37.5 persons/acre (92.7 persons/hectare) [53].

Smart growth is a relevant theory in the study of peri-urban planning and development. Smart growth emerged in 1990s as a solution to the persistent issue of widespread urban sprawl and its numerous unfavorable effects [54–57]. Downs [58] observes that smart growth was conceived in order to eliminate undesirable features such as leapfrog expansion of low-density new development, large-scale conversion of open space and environmentally sensitive lands to urban uses, limited choices of housing types and neighbourhood configurations, traffic congestion and air pollution due to intensive automotive vehicle use, and segregation of land uses as opposed to a blending of uses that cuts down on travel. Smart growth principles include inter alia mixed land uses and pedestrian friendly layouts, compact development or high densities, a variety of housing and transportation choices, open space, and walkable neighbourhoods [55,58–60].

New urbanism is yet another planning theory which is worthwhile in analyzing peri-urban planning and land development. New urbanism is urban design movement that arose in United States in the early 1980s in response to the then conventional suburban planning practices with the objective of countering urban sprawl [36,61]. Through physical design of neighbourhoods, new urbanism strives to achieve social goals of building greater sense of community and redefine public realm through public spaces and streets. New urbanism seeks to create sustainable communities through design policies that promote diversification of land use (mixed-use, mixed-income, mixed-tenure), compact density, and transit-oriented development [61–63].

New urbanism movements consolidate ideas that believe that combination of right architecture, right mix of land uses and public spaces promote sense of community, neighbourliness and identity [43]. New urbanism conglomerates principles of Traditional Neighbourhood Design (TND), Neo-Traditional Design (NTD), Smart Growth, Urban Villages and Transit Orientated Development (TOD), Responsive Environments [35,36,64]. The principles of new urbanism include walkability, connectivity, mixed use and diversity, density and sustainability [49,61]. These theories establish the planning principles; land use mix, accessibility, and density adopted in this study to assess the neighbourhood liveability and sustainability spatial characteristics. Figure 1 illustrates the conceptual model adopted for the study. The research aims to answer the following question: How do fragmented parcel-based land use planning, subdivision and development influence the spatial structure and configuration of peri-urban neighbourhoods of satellite towns?

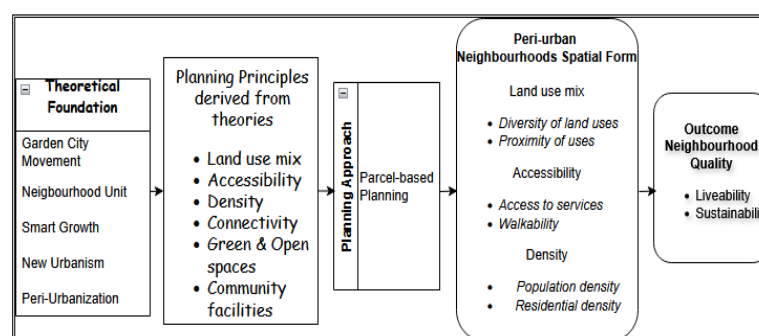


Figure 1. Conceptual model for assessing spatial characteristics of peri-urban neighbourhood for sustainability.

Source: Authors (2026).

3. Methodology

3.1. Case Study Area

The study is based on three peri-urban neighbourhoods in three satellite towns south of Nairobi Metropolitan, Kitengela, Ongata Rongai and Athi River towns, which are situated at $1^{\circ}31'0''$ S, $36^{\circ}50'59''$ E; $1^{\circ}23'37''$ S, $36^{\circ}44'39''$ E; and $1^{\circ}27'27''$ S, $36^{\circ}58'42''$ E, respectively. The three towns form part of the wider Nairobi Metropolitan area and their peri-urban areas are experiencing rapid growth due to proximity to the city, thus serve as suitable residential areas for a larger number of population working in Nairobi City. Figure 2 shows the location of Nairobi Metropolitan satellite towns with a highlight of the three satellite towns.

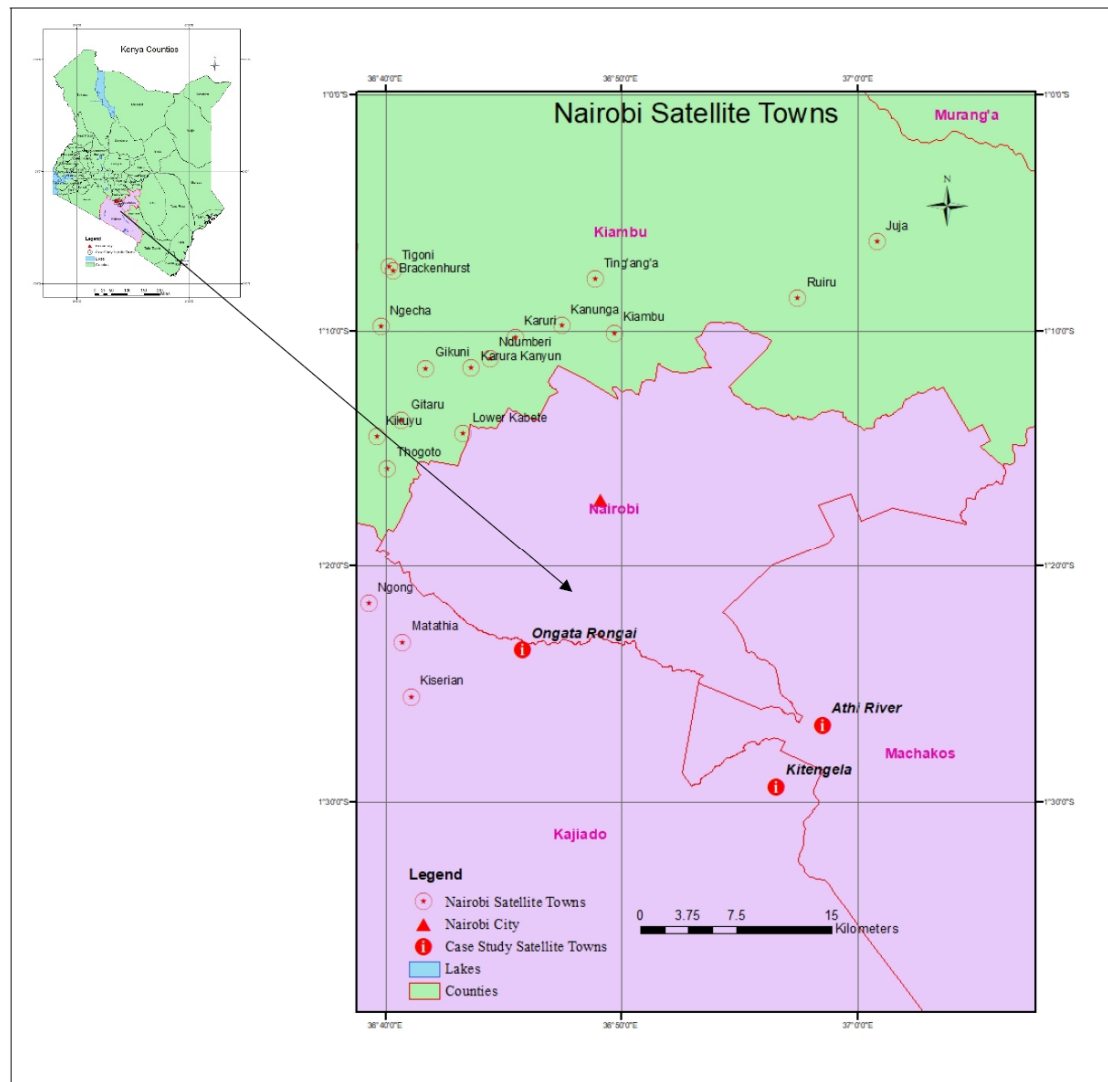


Figure 2. Geographical location of the Southern Nairobi Metropolitan satellite towns of Kitengela, Ongata Rongai and Athi River. Source: Authors (2026).

3.2. Spatial Database

Registry Index Maps (RIMs), cadastral survey plans, land use plans, Google Image and OpenStreetMap are spatial and attribute data sources. Folio Registry Number (FR. No.) was used to compile and obtain required cadastral survey plans from Survey of Kenya. Land use plans in the form of subdivision scheme plan corresponding to each cadastral survey plan were obtained from respective county's Departments of Physical Planning. Cadastral survey plans and RIMs were scanned and georeferenced. The cadastral survey plans grid coordinates based on non-conformal Cassini-Soldner projection (x_i, y_i) were converted to conformal Universal Transverse Mercator (UTM) (X_i, Y_i) by use of a four-parameter transformation of scale, rotation and two translation elements in Excel spreadsheet.

The transformed grid coordinates were used to georeferenced the cadastral survey plans. Parcels and roads as contained in georeferenced survey plans were digitized using ArcGIS 10.5 into shapefiles to create a spatial database. Attribute data, including parcel identification number, abutting FR. No., area of each parcel, and year of

subdivision approval were obtained directly from the survey plans. Planned land uses for each parcel were obtained from approved subdivision scheme plans and entered into parcel shapefile attribute data. The digitized survey plans were overlaid on Google imagery and OpenStreetMap to observe and compile the use of the land. Thirty-six cadastral plans and twelve cadastral plans were used to observe land use allocation in peri-urban neighbourhoods in Athi River Town and Kitengela respectively. The variation in number of cadastral plans used in the study was due to availability of abutting plans forming a neighbourhood which is also a function of frequency of sporadic land use planning and subdivisions. In Ongata Rongai locality, two RIMs were used because RIMs contain all the subdivisions within an entire registration section. The land subdivisions within Athi River Town and Kitengela localities are characterized by fixed boundaries while Ongata Rongai locality is composed of general boundaries.

3.3. Spatial Characterization Measures

The study examined liveability of peri-urban neighbourhoods resulting from individual parcel planning, subdivision, and development using spatial measures and characteristics that are focused on the quality of the physical environment. According to Lowry, J. & Lowry, M. [65] numerous spatial metrics have been developed to describe and evaluate urban shape. Such metrics include inter alia density, street connectivity, land mix, centrality, and accessibility. Measures of land use mix, accessibility, and density were selected to analyze the neighbourhoods because of the possibility of extraction of such data from cadastral and land use plans.

3.4. Data Analysis

Analysis was carried out at two levels. At the first level of analysis, the distinctive characteristics of land use allocation in parcel-based planning is explored within an individual cadastral and land use plan using the chosen liveability spatial indicators. The second level of analysis is carried out using the same spatial elements at a consolidated level of several abutting cadastral survey plans. The parcel-based planned subdivisions are consolidated to form a ‘neighbourhood’ which is then assessed for liveability using land use mix, proximity, and density indices. Land use mix, accessibility and density indices shown in Table 1 were adopted since they characterize quality of the physical environment within individual parcel subdivisions and developments plans and at the conglomeration of several of such plans forming a neighbourhood.

Table 1. Indexes for assessing land use mix, proximity and density in parcel-based planned neighbourhoods.

Index.	Description	Interpretation
Land-use count (Frequency)	Number of land uses present in specified units of analysis.	Higher number implies a higher intensity of land uses.
Area Percentages	Percentage of each land-use category.	High percentage would imply a larger dominance by a single land use.
Entropy Index	The relative percentage of two or more land use types within an area.	The value ranges from 0 to 1, where 0 indicates homogeneous land use and 1 implies the even distribution of the number or area of all land use types. Higher levels of Entropy correspond with greater land use mixture.
Distance measures	Euclidean distance between residential land use and non-residential land uses	Shorter distance implies higher levels of proximity to a specified facility
Gross residential density	Number residential parcels per hectare	Higher number implies a higher number of residential parcels per hectare
Net parcel density	Number residential parcels per hectare of land allocated for residential use	Higher number implies a higher number of residential parcels per hectare

Source: Authors (2026).

Euclidean distance rings of 0–400, 400–800, and 800–1200 m from parcel centroids to different land use category parcels were calculated using geographical information system (GIS) and the number of parcels with centroids within the rings generated. The Euclidean distance was adopted for evaluation of preliminary spatial accessibility due to limited data on type of development (gated community, apartment development, detached housing etc.) and road network characteristics. The 400 m (5 min walking distance) is considered in most literature as the theoretical walkable neighbourhood radius from residence to social infrastructure facilities [66,67]. The paper uses two indices to evaluate neighbourhood density, parcel size (minimum, average, and maximum plot size) and gross parcel density. Gross parcel density is calculated as number of parcels per hectare. In analyzing land use mix, the land uses were classified as residential, industrial, educational, recreational, public purpose, public utilities, commercial, transportation, conservation, agriculture and water bodies.

4. Results and Analysis

4.1. Parcel-Based Planning

Land use changes from rural to urban use in the peri-urban areas are characterized by a series of land use planning, subdivisions, and developments taking place at different times (Table 2). Land in urban core is held under leasehold, while land in peri-urban areas is under freehold tenure, which constrains public control over land use, leading to fragmented and uncoordinated planning and development. The formal process of subdivision of a large parcel under rural use into smaller parcels is initiated by a land owner or developer (client) through engagement of a registered planner and a licensed surveyor as consultants. Each parcel undergoes an independent planning and subdivision process tailored to the needs of the client.

Parcel-based land use planning and subdivisions predominantly concentrate on allocating land parcels for urban residential, commercial, and industrial uses since other uses such as public purpose, public utilities, and recreation uses do not yield direct benefits to private land owners. Figure 3 shows sample neighbourhoods created by planning and subdivision of different parcels. In parcel-based planning, it is stipulated that the necessity to allocate land for public purpose is identified and planned by the planner and surrendered by the land owner. Parcel-based planning, however, encompasses multiple scenarios including planning and subdivision of large parcels into multiple parcels that require allocation and surrender of land for public use; subdivision of medium-sized parcels into a smaller number of parcels that may not require allocation and surrender of land for public purpose; and subdivision of a parcel into two parcels that does not require allocation and surrender of land for public purpose.

Land use planning is undertaken on piecemeal basis, with the planning fees borne by the land owners, which limits resources available to planners compared to comprehensive planning, resulting in land use planning without baseline studies and meaningful public participation. Consequently, approvals are done by planning authorities without detailed plans for provision of utilities, including water and power supply, sewer lines, drainage systems, and storm water management. Once subdivision plans are approved, subdivisions are carried out by surveyors generating diverse parcel sizes and configurations for different subdivisions for the locality, resulting in variation in parcel sizes for similar land uses and land parcels as depicted in Table 2, which vary also from parcel to parcel as shown in Figure 3. Some residential plot subdivisions do not adhere to the minimum residential plot size standard for high density of 0.045 ha due to lack of approved comprehensive development, zoning or subdivision plan for the locality.

Parcel-based land use planning, subdivisions and developments lack implementation plan, continuous monitoring, evaluation, and updating. Table 2 shows variations in years of authentication (approval) of subdivision plans from 1950s to 2010s. Once mother parcel is subdivided, the new parcels are either sold, kept for speculation or developed. Land development in parcel-based land use planning is characterized by three development models, planned development unit (PDU), mixed development, and incremental development. Planned development unit occurs when a large parcel is subdivided into multiple parcels and developed uniformly in adherence to approved development plan. PDU is regulated, planned, and coordinated by a developer which may be a savings and credit cooperative (SACCO), real estate company or government agency. Mixed development occurs when subdivision parcels are sold to several buyers who develop the parcels at different times with adherence to development controls. In incremental approach, development occurs plot by plot at different times without neighbourhood development controls based on the availability of resources, individual needs, or market demand. Parcel-based land use planning is characterized by multiple housing typologies within a single area since subdivision plans are prepared without a clearly articulated overarching development plan.

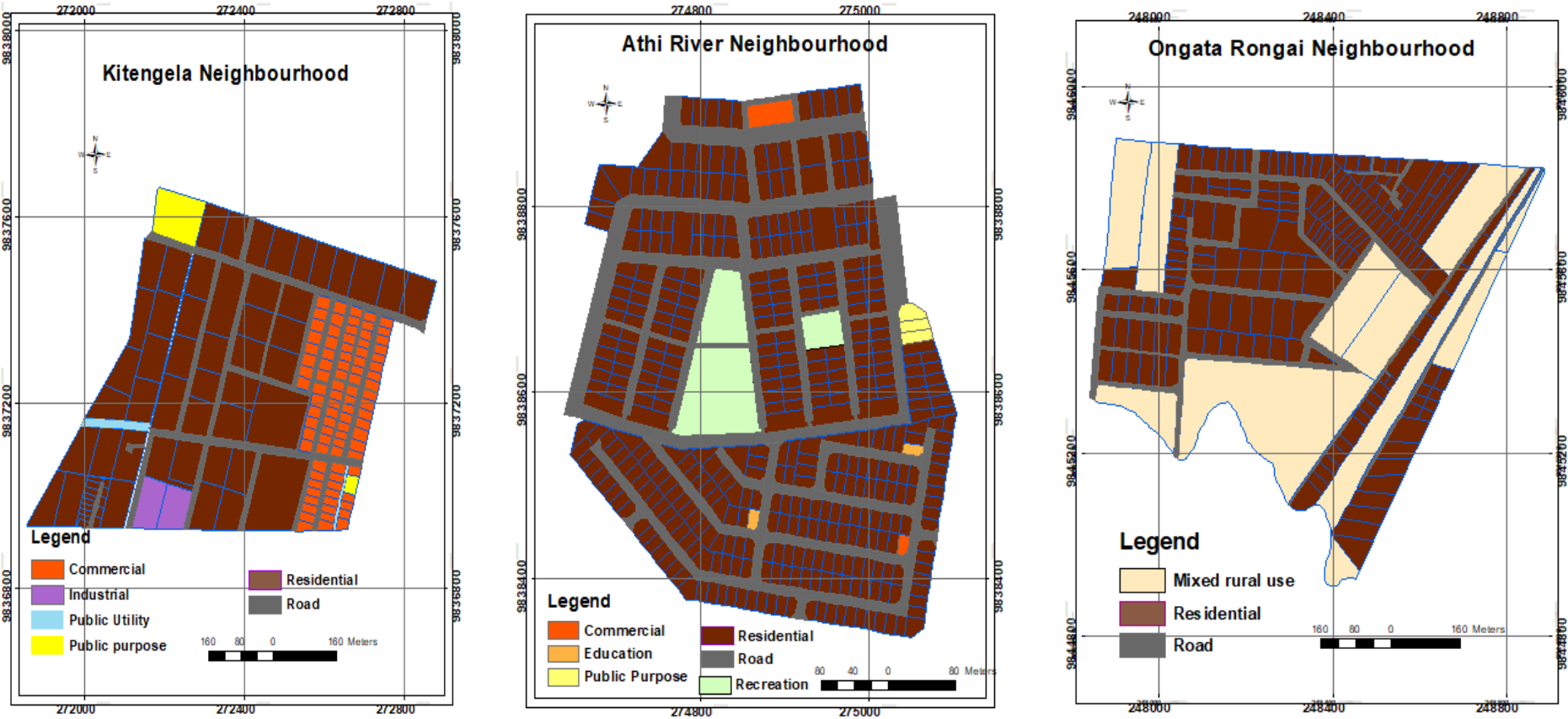


Figure 3. Sample land use distribution per parcel in the peri-urban neighbourhoods of the three satellite towns south of Nairobi Metropolitan. Source: Authors (2026).

Table 2. Land use allocation in different parcels' subdivisions schemes in peri-urban neighbourhoods of the three satellite towns south of Nairobi Metropolitan.

Location	FR No.	Year of Subdivision Approval	Total Subdivision Area (ha)	Number of Land Use Types	Proportion of Land Allocation (ha)										Total Number of Parcels Generated	Number of Parcels Developed	
					0	1	2	3	4	5	6	7	8	9			10
1	131-90	2000	1.103	1	0	1.103	0	0	0	0	0	0	0	0	0	0	0
2	241-83	1993	91.8084	3	0	80.6496	0	0	0	0	2.1578	9.001	0	0	0	57	12
3	229-7	1993	102.7712	2	0	86.1901	0	0	0	0	0	16.5811	0	0	0	74	53
4	239-6	1993	107.2429	2	0	88.3379	0	0	0	0	0	18.905	0	0	0	87	8
5	253-38	1994	7.766	5	5.9361	0	0.0574	0	1.3647	0.0271	0	0.3807	0	0	0	219	219
6	221-97	1992	7.1447	6	5.7021	0.1078	0.0988	0.3914	0.1054	0	0	0.7391	0	0	0	63	42
7	306-6	1994	0.6665	3	0.4339	0	0	0	0	0.1763	0	0.0562	0	0	0	14	9
8	157-39	1982	4.808	3	2.1999	0	0	1.161	0	0	0	1.4471	0	0	0	67	64
9	157-40	1982	4.5049	3	3.3137	0	0	0.1752	0	0	0	1.0161	0	0	0	91	84
10	127-73	1976	4.4498	3	2.3815	0	0	0	0.136	0	0	1.9323	0	0	0	45	39
11	206-177	1991	9.6546	2	9.184	0	0	0	0	0	0	0.4706	0	0	0	2	1
12	75-43	1956	3.17	2	2.6886	0	0	0	0	0	0	0.4814	0	0	0	40	40
13	220-173	1992	0.1992	1	0.1992	0	0	0	0	0	0	0	0	0	0	4	0
14	299-77	1992	1.4658	1	1.4658	0	0	0	0	0	0	0	0	0	0	1	0
15	73-145	1956	1.2924	1	1.2924	0	0	0	0	0	0	0	0	0	0	11	11
16	261-73	1996	11.237	6	3.5046	0	0.1691	0.546	0.3271	1.4275	0	5.2626	0	0	0	153	123
17	186-33	1987	9.1641	3	0	7.6619	0	0	0	0.1849	0	1.3173	0	0	0	3	3
18	145-61	1980	6.5428	4	2.47	1.524	2.2084	0	0	0	0	0.3404	0	0	0	11	11
19	145-60	1979	33.4208	2	24.234	0	0	0	0	0	0	9.1867	0	0	0	34	34
20	76-30	1956	165.4637	4	18.393	137.814	0	0	1.7341	0	0	7.5228	0	0	0	7	6
21	142-84	1977	10.4174	2	0	9.235	0	0	0	0	0	1.1824	0	0	0	7	6
22	242-1	1992	2.2825	2	0	1.78	0	0	0	0	0	0.5024	0	0	0	1	1
23	240-84	1993	0.5928	1	0	0.5928	0	0	0	0	0	0	0	0	0	3	0
24	148-124	1981	0.4939	1	0	0.4939	0	0	0	0	0	0	0	0	0	2	0
25	178-14	1986	3.1549	4	0.485	0	0	0.3107	0	0.6342	0	1.7249	0	0	0	5	4
26	390-33	2001	0.5761	2	0	0	0	0	0	0.5665	0	0.0096	0	0	0	4	4
27	332-56	1998	0.3971	1	0	0	0	0	0	0.3971	0	0	0	0	0	7	7
28	406-148	2002	2.0011	2	0	0	0	1.2824	0	0	0.7187	0	0	0	0	1	1
29	71-501	1962	2.7044	2	2.1552	0	0	0	0	0	0	0.5492	0	0	0	1	1
30	240-27	1993	0.2933	2	0.1078	0	0	0	0	0.1855	0	0	0	0	0	2	2
31	100-185	1963	0.1609	1	0	0	0	0	0	0	0	0.1609	0	0	0	1	0
32	102-64	1964	0.7907	2	0	0	0	0	0	0	0.7276	0.0631	0	0	0	19	19
33	90-180	1960	1.1753	2	0	0	0	0	0.5596	0	0	0.6156	0	0	0	3	3
34	255-96	1995	2.6411	4	0	0.8156	0	0	0.6296	0	0.3917	0.8042	0	0	0	10	9
35	125-29	1975	17.4667	4	13.412	0	0	0.6468	0.2339	0	0	3.1743	0	0	0	215	178
36	125-30	1975	13.0504	2	10.513	0	0	0	0	0	0	2.5374	0	0	0	164	138
Totals			632.0744		110.0718	416.3056	2.5337	4.5135	5.0904	3.5991	3.9958	85.9644	0	0	0	1428	1132

Table 2. Cont.

Location	FR No.	Year of Subdivision Approval	Total Subdivision Area (ha)	Number of Land Use Types	Proportion of Land Allocation (ha)										Total Number of Parcels Generated	Number of Parcels Developed	
					0	1	2	3	4	5	6	7	8	9			10
Percentage land use type allocation					17.41	65.86	0.4	0.71	0.81	0.57	0.63	13.60	0	0	0		
1	424-9	2002	3.4724	3	2.4926	0	0	0	0.3191	0	0	0.6607	0	0	0	52	16
2	231-44	1992	11.1974	4	6.3089	0	0	0.6959	1.9279	0	0	2.2647	0	0	0	120	116
3	173-82	1985	28.280	3	23.378	1.273	0	0	0	0	0	3.629	0	0	0	36	35
4	173-83	1984	6.3011	2	0	0	0	0	0	4.7336	0	1.5675	0	0	0	68	66
5	524-76	2012	2.0448	1	0	2.0448	0	0	0	0	0	0	0	0	0	2	2
6	173-86	1984	2.1647	4	0	0	0	0	0.1199	1.4302	0.0825	0.5321	0	0	0	22	22
7	412-33	2002	0.5692	2	0	0	0	0	0	0.4292	0	0.14	0	0	0	6	6
8	296-88	1996	0.2218	2	0	0	0	0	0	0.1812	0	0.0406	0	0	0	3	3
9	173-84	1985	4.8345	3	0	0	0	0	0.6495	3.3867	0	0.7983	0	0	0	66	66
10	204-96	1990	0.595	2	0	0	0	0	0	0.3426	0	0.2524	0	0	0	1	1
11	263-83	1996	10.2457	4	8.5638	0	0	0	1.1855	0	0.2816	0.2148	0	0	0	15	13
12	586-165	2016	0.6619	2	0.5708	0	0	0	0	0	0	0.0911	0	0	0	14	2
Totals			70.5885		41.3141	3.3178	0	0.6959	4.2019	10.5035	0.3641	10.1912	0	0	0	405	348
Percentage land use type allocation					58.53	4.70	0	0.99	5.95	14.88	0.52	14.44	0	0	0		
1	SHEET148/3/15S E	2004–2014	60.0748	2	54.064	0	0	0	0	0	0	6.0108	0	0	0	192	-
2	SHEET148/3/15S E & SHEET 148/4/11SW		53.1093	2	48.017	0	0	0	0	0	0	5.0923	0	0	0	260	-
3	SHEET148/4/11SW	2007–2014	105.6452	2	99.63	0	0	0	0	0	0	6.0152	0	0	0	431	-
Totals			218.8293		201.711	0	0	0	0	0	0	17.1183	0	0	0		
Percentage land use type allocation					92.18	0	0	0	0	0	0	7.82	0	0	0		
Land Use Codes			Residential (0)		Industrial (1)		Educational (2)		Recreational (3)		Conservation (8)		Agriculture 9				
			Public Purpose (4)		Commercial (5)		Public Utilities (6)		Transportation (7)		Water Bodies 10						

Source: Authors (2026).

4.2. Land Use Type Frequency

Figure 4 shows frequency of allocation of land use types within the 36 and 12 subdivision plans in Athi River and Kitengela neighbourhoods, respectively. In Athi River neighbourhood, the number of land use types in subdivision plans varied from 1 to 6. The maximum mix of 6 land use types includes a combination of residential, industrial, educational, recreational, public purpose, and transportation, while the single land use type was mainly residential. Transportation (roads) had total occurrence of 27, followed by residential at 20 and industrial at 13, with some allocation for educational, recreation, public purpose, commercial and public utilities in planning for peri-urban land subdivisions in Athi River neighbourhood. Conservation, agriculture and water body land use types did not have any allocation in peri-urban land subdivisions.

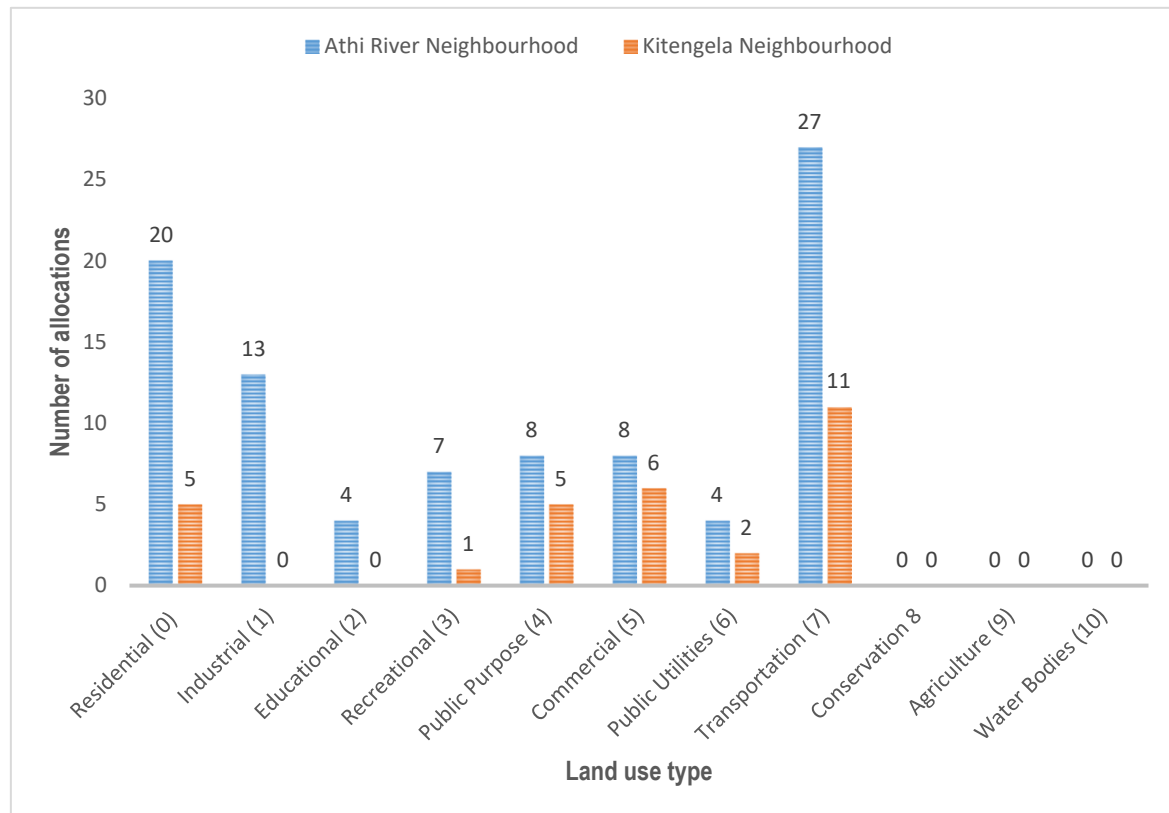


Figure 4. Frequency of land use type allocations in the subdivision schemes of the peri-urban neighbourhoods of Athi River and Kitengela. Source: Authors (2026).

The number of land use types in subdivision scheme plans in Kitengela varied from 1 to 4. Transportation use (roads) dominates with a frequency of 11 occurrences, with significant allocation to residential at 5, commercial at 6, and public purpose land use occurring 5 times in subdivision schemes (Figure 4). While residential, commercial and public purpose use types dominate the locality in terms of frequency of allocation, education facility, industrial, conservation, agriculture, and water bodies land use types are not planned for in the subdivision schemes in Kitengela. Unlike Kitengela and Athi River which have fixed boundary, Ongata Rongai neighbourhood is predominantly general boundary. The RIMs are continuously being amended to accommodate new approved subdivisions. Land allocation in the chosen Ongata Rongai locality is dominantly residential supported by transportation.

Year of authentication of cadastral plans provide temporal trends in analysing land use mix allocations over the years. Subdivisions in Athi River neighbourhood range from as early as year 1956 to 2000s. Progressive diversification of land use is observed with more mixed-use subdivisions observed post-1970s (Table 3) where years of authentication are categorized in decades. The years 1950s and 1960s land use type allocation in subdivisions in Athi River neighbourhood comprised of industrial, residential, public purpose, public utilities and transportation uses. The 1970s and 1980s Athi River neighbourhood diversity improved by allocation of industrial and residential land use types and integrating educational, recreational, and commercial use areas. Allocation of land to residential and industrial increased in the 1990s and 2000s with spontaneous allocation to educational, recreational and commercial areas.

Table 3. Number of land use types in the subdivision schemes of the peri-urban neighbourhoods of Athi River and Kitengela over the years.

	Year of Subdivision Approval	Total Subdivision Area (ha)	Number of Subdivisions	Average Number of Land Use Types	Maximum Number of Land Use Types
Kitengela	1980s	40.4635	4	3	4
	1990s	22.2599	4	3	4
	2000s	4.0416	2	3	3
	2010s	2.7067	2	2	2
Athi River	1950s	169.9261	3	2	4
	1960s	4.8313	4	2	2
	1970s	78.8051	5	3	4
	1980s	28.6686	6	3	4
	1990s	346.1631	15	3	6
	2000s	3.6802	3	2	2

Source: Authors (2026).

The subdivisions in Kitengela neighbourhood range from 1980s to early 2010s. Unlike Athi River neighbourhood, land subdivisions planning in the Kitengela neighbourhood is characterized by high land use diversity allocation (Table 3). The 1980s subdivisions in Kitengela neighbourhood comprised of allocation for residential, commercial, industrial, public purpose, public utilities and transportation. Apart from allocation for transportation, allocation for commercial use is observed to be dominant since it is featured in three subdivisions, whereas residential and industrial use allocations is featuring once in the 1980s subdivision in the Kitengela neighbourhood. The 1990s subdivision allocations in the Kitengela neighbourhood replicated the 1980s except that there was no allocation for industrial use but for recreation use in the 1990s. The 2000s and 2010s allocation in subdivision schemes in the Kitengela neighbourhood comprised residential, industrial, commercial, public purpose and transportation use.

The study of temporal trends in land use mix of two neighbourhoods of Athi River and Kitengela indicate planning precedence of establishing living (residential) and working (industrial and commercial use) spaces with supporting transportation infrastructure in fragmented planning. Education, recreation, and public purpose use types are observed to be planned based on rising demand from already established living and working spaces. Gradual increase in number of land use types with time is observed in both neighbourhoods depicting neighbourhood achievement of sustainability status as in comprehensive planning.

4.3. Land Use Types Allocation Proportions

The proportion of land use allocation in Athi River neighbourhood subdivision schemes indicate higher allocation for residential and industrial uses with supporting allocation to transportation infrastructure to provide accessibility to created residential plots with limited integration of commercial, public utilities, public purpose, and recreational. Out of the total subdivision area approximately 632.07 hectares across 36 subdivision schemes in the chosen Athi River neighbourhood, majority of land is allocated to industrial use (about 416.3056 hectares), followed by residential (110.0718 hectares), transportation (85.9644 hectares) and smaller proportions allocated to educational (2.5337 hectares), recreational (4.5135 hectares), public purpose (5.0904 hectares), commercial (3.5991 hectares), and public utilities (3.9958 hectares) as shown in Table 2. The area of subdivision schemes in the chosen Kitengela neighbourhood totaled approximately 70.58 hectares across 12 subdivision schemes. Majority of land in Kitengela neighbourhood is allocated to residential (41.3141 hectares), commercial (10.5035 hectares), transportation (10.1912 hectares), public purpose (4.2019 hectares), industrial use (3.3178 hectares), and smaller allocations to recreational (0.6959 hectares), and public utilities (0.3641 hectares).

Land allocation in the Ongata Rongai neighbourhood is for residential and rural use with supplementing transportation use. A total of 218.8293 hectares was derived from three locations in two registry index maps (RIM). The first locality derived from RIM SHEET 148/3/15/SE had approximately 60.0748 hectares out of which 54.064 hectares allocated for residential use and 6.0108 hectares allocated for transportation. The second locality comprising overlapping subdivisions was derived from a combination of SHEET 148/3/15/SE and SHEET 148/4/11/SW had approximately 53.1093 hectares with 48.017 hectares allocated for residential use and 5.0923 hectares allocated for transportation. The third locality derived from SHEET 148/4/11/SW had 105.6452 hectares out of which 99.63 hectares allocated for residential use and 6.0152 hectares allocated for transportation.

Residential land use predominates the neighbourhoods of Kitengela and Ongata Rongai peri-urban localities while industrial land use type is dominant in Athi River peri-urban neighbourhood. Athi River neighbourhood exhibit diverse land use mix with subdivisions containing up to six different land use types with allocation to almost all the land use types with exception of conservation, agriculture and water body use types. Kitengela and

Ongata Rongai neighbourhoods generally have fewer land use types per subdivision scheme, predominantly featuring residential and public utilities land uses but missing allocation for education use.

4.4. Subdivision Land Size and Land Use Mix Nexus

The influence of the size of the mother parcel on diversity in allocation of land use in parcel-based planning and subdivision is assessed using Spearman's rank-order correlation. The correlation of the size of the mother parcel and land use type count was carried out for the Athi River and Kitengela neighbourhood localities. The two correlations are as demonstrated in Figure 5. Land subdivision and development in Athi River locality revealed a moderate positive association ($r_s = 0.586$, $p = 0.0019$, $n = 36$) between the size of mother parcel and the number of allocated land use types. Similarly, the Kitengela neighbourhood locality depicted a moderate-to-strong positive correlation ($r_s = 0.641$, $p = 0.0835$, $n = 12$). This demonstrates slight increase in diversity of land use types with increases in subdivision mother parcel size in parcel-based land use planning, subdivisions and development. The Ongata Rongai locality subdivisions' data was generated from two registry index maps and RIM's overlaps ($n = 3$) and had only two land use types irrespective of mother parcel size thus hindering correlation assessment.

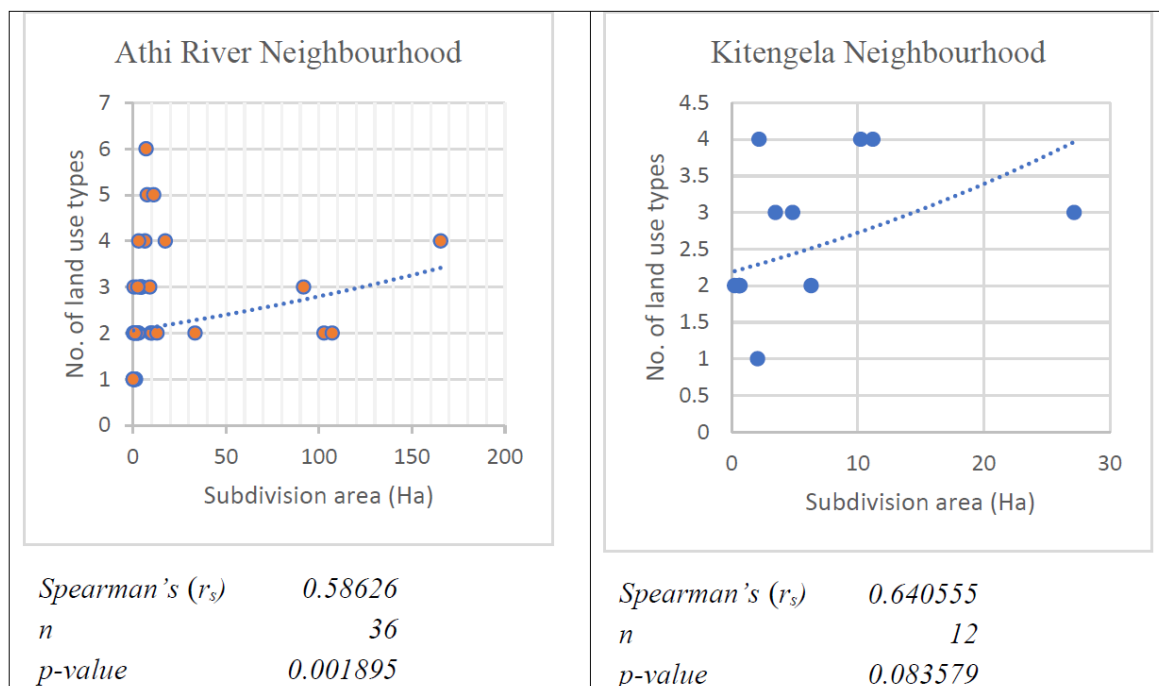


Figure 5. Correlation between subdivision area and land use type count in the subdivision schemes of the peri-urban neighbourhoods of Athi River and Kitengela. Source: Authors (2026).

4.5. Entropy Index

The entropy index was computed using Equation (1). A summary of entropy index for the three neighbourhoods are shown in Table 4. The average land use mix pattern is observed to be higher in Kitengela neighbourhood than Athi River and Ongata Rongai neighbourhood. The entropy index begins at 0 in six subdivisions in Athi River and one subdivision in Kitengela neighbourhoods depicting subdivisions with allocation to single land use type. The highest entropy index of 0.9 is observed in five out of the thirty-six subdivisions in the Athi River neighbourhood which implies almost equal size allocation to at least two land uses in the five subdivision plans. Even though higher entropy index implies an almost balance allocation of land use types, it is observed that higher entropy index does not necessarily imply mixing of many land use types since even proportionate allocation of two land uses scores very high (0.9–1) entropy index.

$$ENT = - \frac{\sum_{i=1}^N (P_i \ln P_i)}{\ln(N)} \quad (1)$$

where

ENT = Entropy Index Value

P_i = Proportion of land-use type i in the subdivision plan

N = Total number of land-use categories in the subdivision plan

Table 4. Entropy index of land use mix in peri-urban neighbourhoods of the three satellite towns.

<i>Neighbourhood</i>	<i>Minimum</i>	<i>Average</i>	<i>Maximum</i>
Athi River	0.0	0.5	0.9
Kitengela	0.0	0.6	0.8
Ongata Rongai	0.3	0.4	0.4

Source: Authors (2026).

The Ongata Rongai neighbourhood had a minimum entropy index of 0.3 implying the absence of a subdivision with only one single land use type like the Athi River and Kitengela neighbourhoods. The maximum entropy index in Ongata Rongai neighbourhood is lower at 0.4 owing to subdivision allocation to residential and transportation use which cannot be proportionate. The variance in entropy index in the neighbourhoods indicate random allocation of land use types on need basis in parcel-based peri-urban planning.

4.6. Land Use Proximity

Proximity of diverse land use types is assessed in the neighbourhoods using sample location. For adequate representation of the sample locations, the selection criteria for subdivision plans included the presence of abutting subdivision plans, diverse planned land use categories of the resulting parcels, and a high number of parcels generated from the parent parcels. Five subdivision plans with intense subdivision resulting in 462 parcels of diverse sizes and uses were used to assess proximity of diverse land use types in the Athi River neighbourhood. The 462 parcels selected for the proximity study constitute approximately one-third (32.35%) of the resultant 1428 parcels. The outcome of the aggregation of the five plans created a sample neighbourhood with six land use types i.e., residential, commercial, recreation, public purpose, education, and transportation. Residential land use type dominated the allocation in the five subdivision schemes with 452 parcels out of the 462 parcels allocated to residential use. In the sampled Athi River neighbourhood, proximity is thus considered as the Euclidean distance between residential land use and commercial, recreation, public purpose, and education. The Athi River neighbourhood has two commercial land use allocation at different locations ensuring that all residential parcels are within 0 to 400 m Euclidean distance to commercial land use space. The recreation facility (open space) in this Athi River neighbourhood is also within 0 to 400 m Euclidean distance to all residential land use parcels in the vicinity. The minimum Euclidean distance from Athi River neighbourhood residential land use parcels to public purpose use is 24.17 m and the maximum Euclidean distance is 469.52 m. Out of the 452 allocated residential use, 436 parcels are within 0 to 400 m Euclidean distance to the public purpose use while the remaining 16 are within 401 to 800 m. There exist two parcels allocated education use in the Athi River neighbourhood leading to 403 parcels of residential use falling within 0 to 400 m Euclidean distance to an education facility and 49 parcels within 401 to 800 m from education facility. These findings establish that public purpose use are within walkable distance in the neighbourhood. The Athi River neighbourhood lack access to health and religious facilities within the vicinity.

Similar to Athi River neighbourhood, five subdivision plans were considered in neighbourhood proximity assessment of Kitengela neighbourhood. This resulted in a neighbourhood comprising 155 parcels. The 155 parcels selected for the study constituted approximately 38.3% of the resultant 405 parcels. These parcels were dominated by either residential or commercial use. Commercial use was allocated to 89 parcels while residential use had 62 parcels, industrial use and public purpose each had allocation of 2 parcels. The other land use allocation in this Kitengela neighbourhood was for transportation (street) and public utilities (power line and sewerage lane). Proximity to industrial use indicate the minimum Euclidean distance from Kitengela neighbourhood residential land use parcels to industrial use is 95.10 m and the maximum Euclidean distance is 787.29 m. Out of the 62 parcels allocated residential use, 40 parcels are within 0 to 400 m Euclidean distance to the industrial use while the remaining 22 are within Euclidean distance of 401 to 800 m. The minimum Euclidean distance from residential land use parcels to public purpose is 89.27 m and the maximum Euclidean distance is 701.26 m. It is observed in this Kitengela neighbourhood that planned education, health, recreation and religious facilities are not available within 0 to 800 m for the 62 residential use parcels thus limiting neighbourhood walkability. This Kitengela neighbourhood is thus planned for living (residential) and working (industrial and commercial) activities.

The chosen Ongata Rongai neighbourhood is observed to be a peri-urban with very active transition from rural to urban still taking place. The parcel-based land use planning, subdivision, and developments in this neighbourhood create living spaces (residential) with supporting street network. There is still no planned allocation for education, health, recreation, public purpose, and religious facilities in this Ongata Rongai neighbourhood hence no proximity evaluation. However, there exists parcels (Figure 3) which are still under mixed rural use (residential and agriculture) where some facilities can be created on need basis.

4.7. Neighbourhood Residential Density

Diverse residential land use density varied in subdivisions in all the neighbourhoods as depicted in Table 5. In Athi River neighbourhood, a total of 17 subdivision scheme plans out of the 36 had land allocation to residential use. The Athi River neighbourhood has a maximum gross and net residential density of 27.43 and 35.88 residential parcels per hectare respectively and a minimum a gross and net residential density of 0.15 and 0.22 residential parcels per hectare. Out of the 12 subdivision scheme plans in the Kitengela neighbourhood, 5 schemes had residential land use with a maximum of gross and net residential density of 21.15 and 24.53 residential parcels per hectare respectively and a minimum a gross and net residential density of 1.25 and 1.53 residential parcels per hectare. The congregated subdivisions in the 3 registry index maps in Ongata Rongai portrays lower densities compared to the Athi River and Kitengela neighbourhoods. The noted minimum gross and net residential density in the Ongata Rongai neighbourhoods are 3.20 and 3.55 residential parcels per hectare respectively while the maximum gross and net residential density are 4.90 and 5.41 residential parcels per hectare. The low densities in Ongata Rongai neighbourhood is an indication of locality still undergoing transition. The diverse residential density in neighbourhoods is an indication of lack of density standards in peri-urban parcel-based land use planning, subdivisions and developments. The Physical and Land Use Planning Handbook [68,69] specify residential density of 1–4, 5–20, and 20 residential parcels per hectare and above for low, medium, and high residential density respectively. The results from the three neighborhoods indicate mix-up densities in neighborhoods resulting from parcel-based land use planning, subdivision and development. This makes it difficult to classify neighborhoods in terms of densities which is vital in provision of supporting facilities.

In the same vein of neighbourhood densities, residential parcel sizes vary in subdivision plans of the same neighbourhood as shown in Table 5. The minimum parcel size in the study area of Athi River, Kitengela, and Ongata Rongai neighbourhoods are 0.0201, 0.0349 and 0.018 hectares respectively while the maximum for the same are 5.0003, 2.0258, and 11.4158 hectares. The Physical and Land Use Planning Handbook sets minimum plot size of 0.045, 0.10 and 0.2 hectares for high, medium, and low density developments respectively [68,69]. From the 17 subdivision plans with residential land use in Athi River, a total of 8 subdivision plans have some parcels of residential use with size below the minimum standard plot size of 0.045 ha for high density development. In Kitengela neighbourhood 3 subdivision plans out of 5 subdivision scheme plans with residential use allocation have some parcels size below 0.045 ha, similarly Ongata Rongai neighbourhoods have some parcels of sizes below the 0.045 ha.

According to the Physical and Land Use Planning (Building) Regulations [69], the minimum parcel size within a specific area is set by a development plan, advisory plan, zoning plan, and subdivision plan approved by the planning authority. However, peri-urban areas are undergoing expansion based on subdivision plans (which lack development controls) initiated at different times by different land owners and developers—individuals, savings and credit cooperative societies (SACCOS) and real estate companies—whose interests are unregulated profiteering from land sale or development. Due to lack of comprehensive plans or zoning regulations, and corruption in land subdivision approval, sizes, shapes and alignments of parcels generated in parcel-based planning vary depending on each individual subdivision plan as shown in Figure 3. There is limited adherence to the requirement that planned residential plots should be rectangular, or close to rectangular, depending on the topography as recommended by the Physical and Land Use Planning Handbook [69].

Table 5. Neighbourhood densities of localities of peri-urban neighbourhoods of the three satellite towns.

Location	FR No.	Total Subdivision Area (ha)	Net Residential area (ha)	Minimum Residential Plot Size (ha)	Maximum Residential Plot Size (ha)	Mean Residential Plot Size (ha)	Number of Residential Parcels	Gross Residential Density (#Residential Parcels /ha)	Net Residential Density (#Residential Parcels /ha)
<i>Athi River</i>	253-38	7.7660	5.9361	0.0237	0.0543	0.0279	213	27.43	35.88
	221-97	7.1447	5.7021	0.0531	0.1599	0.0966	59	8.26	10.35
	306-6	0.6665	0.4339	0.0301	0.0635	0.0433	10	15.00	23.05
	157-39	4.808	2.1999	0.0286	0.1130	0.0338	65	13.52	29.55
	157-40	4.5049	3.3137	0.0286	0.1341	0.0326	90	19.98	27.16
	127-73	4.4498	2.2455	0.0385	0.0510	0.0972	45	10.11	20.04
	206-177	9.6546	9.184	4.1838	5.0003	4.592	2	0.21	0.22
	75-43	3.17	2.6886	0.039	0.1484	0.0672	40	12.62	14.88
	220-173	0.1992	0.1992	0.049	0.0505	0.0498	4	20.08	20.08
	299-77	1.4658	1.4658	1.4658	1.4658	1.4658	1	0.68	0.68
	73-145	1.2924	1.2924	0.085	0.1627	0.1175	11	8.51	8.51
	261-73	11.237	3.5046	0.0201	0.0598	0.0295	119	10.59	33.96
	145-61	6.5428	2.47	2.47	2.47	2.47	1	0.15	0.40
	71-501	2.7044	2.1552	2.1552	2.1552	2.1552	1	0.37	0.46
	240-27	0.2933	0.1078	0.1078	0.1078	0.1078	1	3.41	9.28
	125-29	17.4667	13.4116	0.0339	0.1092	0.063	212	12.14	15.81
	125-30	13.0504	10.513	0.0505	0.6489	0.0641	164	12.57	15.60
<i>Kitengela</i>	424-9	3.4724	2.4926	0.0423	0.0655	0.0473	51	14.69	20.46
	231-44	11.1974	6.3089	0.039	0.8531	0.0853	117	10.45	18.55
	173-82	28.280	22.2521	0.4276	2.0258	0.6545	34	1.25	1.53
	263-83	10.2457	8.5638	0.5601	0.6676	0.6117	14	1.37	1.63
	586-165	0.6619	0.5708	0.0349	0.0563	0.0408	14	21.15	24.53
<i>Ongata-Rongai</i>	SHEET 148/3/15/SE	60.0748	54.0643	0.0404	7.3089	0.2816	192	3.20	3.55
	SHEET 148/3/15/SE & SHEET 148/4/11/SW	53.1093	48.0168	0.0385	2.0694	0.1847	260	4.90	5.41
	SHEET 148/4/11/SW	105.6452	99.6298	0.018	11.4158	0.2311	431	4.08	4.33

Source: Authors (2026).

5. Discussions

The findings indicate that parcel-based planning primarily focuses on allocation of residential land uses and economic activities particularly industrial and commercial land uses. In contrast, relatively limited attention is given to neighbourhood liveability parameters such as land-use mix, residential density, and availability of public spaces in piecemeal parcel-based planning. The land-use entropy values observed in this study, ranging from 0.0 to 0.9, differ from those reported in other neighbourhood-scale studies. Notably, the entropy value of 0.0 observed in this study was not reported by Bahadure and Kotharkar [70] or Nkeki and Asikhia [71], whose studies generally reported higher entropy values. This variation reflects land use variation at neighbourhood parcel level. The density assessment results from the three neighbourhoods indicate considerable diversity in density arising from parcel-based land-use planning, subdivision, and development patterns. A recent study of Nairobi similarly demonstrated diverse residential neighbourhoods characterized by varying development densities [72]. The observed heterogeneity in neighbourhood densities is consistent with findings from other rapidly urbanising cities. For example, Komo et al. [73], in their assessment of Riyadh's urban growth boundaries, reported spatially uneven development patterns, highlighting variations in development intensity within the urban area.

Accessibility of essential public facilities including educational institutions, healthcare services, public safety infrastructure, recreational spaces, and governance facilities is not prioritized in parcel-based land use planning in peri-urbanization thus walkability of the resulting congregated neighbourhood is inadequate. These identified shortcomings of piecemeal parcel-based land use planning are consistent with those reported in previous studies in other countries [18,21,23]. Peri-urban expansions are driven by diverse factors and challenges *inter alia* population growth, speculation, land value, land tenure, and government deficits [29,74] that complicate peri-urban land use planning. These findings suggest that reliance only on piecemeal parcel-based land use planning in peri-urban land development is unlikely to produce liveable and sustainable neighbourhoods in peri-urban land use planning, subdivisions and development.

Piecemeal parcel-based land use planning provides a mechanism for guiding development in the face of rapid urbanization in peri-urban areas thereby creating a more structured alternative to completely unplanned expansion. However, parcel-based land use planning and development alone is insufficient to achieve sustainable neighbourhoods in peri-urban developments. Though it contributes to more orderly land development in the absence of comprehensive plans such as master plans, its narrow focus on allocation of land for residential and economic land uses limits its ability to create functional, inclusive, and liveable neighborhoods. Integrating parcel-based planning with comprehensive planning frameworks could help ensure that future development incorporates balanced land-use patterns, adequate public facilities, and improved urban liveability and sustainability.

Despite these findings, the study faced certain limitations. First, the sporadic nature of parcel-based peri-urban land use planning, subdivision and developments made the availability of the parcel-level planning and land use data inconsistent across the study areas restraining the completeness and comparability of cross-neighbourhood characteristics using inferential statistics such as ANOVA or Kruskal-Wallis. Second, some peri-urban neighbourhoods are characterized by general boundaries while some have parcels delineated through fixed boundaries thus presenting different spatial data sources and accuracies. Consequently, the differences reported among neighbourhoods should be interpreted as descriptive variations rather than statistically significant differences. However, the study provides insights into resultant peri-urban neighbourhoods generated through piecemeal land use planning.

6. Conclusions

This paper evaluated land use mix, proximity, and densities of neighbourhoods created through piecemeal parcel-based land use planning in horizontal peri-urban expansion of satellite towns in the Southern Nairobi Metropolitan area. Piecemeal parcel-based land use planning, subdivision, and development create neighbourhoods with a mixed-up land use mix, proximity, and density. Piecemeal parcel-based land use planning, subdivision and development prioritize creation of living (residential land use) spaces and supporting transportation infrastructure with limited provision of working (industrial and commercial use) spaces. Social infrastructure that includes facilities and services that improve quality of life, human well-being, and social development such as education, health and safety, recreation, and governance are infrequently planned for in piecemeal parcel-based land use planning and development. This results in very low land use mix, mixed-up residential densities and limited accessibility. Land use planning regulations are not adhered to due to the fact that piecemeal parcel-based planning, subdivision, and development focus on profitability to the land owner or the developer.

Essential neighbourhood facilities such as education, health and safety, and religious facilities are scarcely planned for and allocated land as public land through acquisition or surrender in parcel-based land use planning,

subdivision and development; this leads to provision of such facilities in the neighbourhood by the private sector based on rising demands. This is done either through authorized or non-authorized change of user. The change of user creates facilities which meet spatial standards such as walking distance, minimum size, and catchment population. Prioritization of residential use in piece-meal parcel-based land use planning leads to creation of neighbourhoods with limited liveability and sustainability. Following adoption of online platforms that allow citizens and stakeholders to access land information and processes, there is a need to incorporate a digital parcel-based land use planning and subdivision approval system that assesses spatial requirements such as proximity to essential facilities, land use mix and densities to aid in evidence-based subdivision approval decision making in order to ensure neighbourhood liveability and sustainability in parcel-based land-use planning.

Author Contributions

G.O.K.: Conception and design, material preparation, data collection, analysis and writing the original draft; S.L.: Conception and design, analysis, review and editing; C.M.: Conception and design, review and editing. All authors have read and agreed to the published version of the manuscript.

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All data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

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