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Mapping the spatial patterns of ethnic segregation and its implications to urban policy in Nairobi city

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Abstract

In modern times, cities around the world have grappled with the challenges of racial and ethnic segregation. In Nairobi city, with its diverse ethnic makeup, there is widening inequalities and emerging patterns of ethnic segregation, where the five main ethnic groups - Kamba, Luo, Kikuyu, Luhyia, and Kisii - experience varying levels of spatial concentration. This study analysed the spatial patterns of ethnic segregation in Nairobi, using geocoded questionnaire data from the 2019 Kenya population and housing census data. We used the Index of Dissimilarity in STATA software and Geo-segregation Analyzer and Anselin's Local Moran I method in GIS to map ethnic segregation patterns. Our findings uncovered a striking socio-spatial divide based on ethnicity. Anselin Local Moran's I indicators further pinpointed areas with the highest levels of segregation and spatial clustering of specific ethnic groups. These findings offer crucial insights for urban planners and policymakers. By pinpointing areas experiencing the most severe spatial segregation, our research could inform spatially targeted interventions and resource allocation. This could inform policies that foster inclusivity, reduce spatial inequalities, and build a more equitable and socially cohesive city.

Keywords Ethnic segregation, Spatial inequality, GIS, Index of dissimilarity, Urban policy

1 Introduction

Ethnic segregation remains a persistent challenge in urban centers worldwide (Bansal, 2021; Hussain & Imitiyaz, 2018; Aggarwal, 2014). A substantial body of research has documented the negative impacts of segregation on the integration of ethnic groups within cities worldwide (Nijman & Wei, 2020; Pacione, 2009; Martinez-Martin, 2005). In Hamburg for instance, Friedrichs (2013) found that, segregation led to discrimination based on socioeconomic status and educational attainment. In US cities, white middle-class families concentrated in middle-class neighborhoods and schools, while Black and Hispanic middle-class families were more likely to reside in disadvantaged areas and send their children to high-poverty schools (Quillian, 2012; Charles, 2003). In addition, a study in Michigan demonstrated that segregation resulted in whites across income levels residing in better neighborhoods than blacks of similar economic standing (Darden et al., 2018). A study of Brussels, Copenhagen, Amsterdam, Oslo, and Stockholm revealed a positive correlation between high levels of ethnic/racial segregation and increased deprivation within those segregated areas (Haandrikman et al., 2023; Harsman, 2006). In South Africa, persistent occupational segregation is evident, with blacks disproportionately concentrated in low-paying jobs compared to Whites (Gradín, 2019). Similar observations were made in Kenya, where ethnic divisions during British rule, marginalized Africans and concentrated minorities in neglected areas (Jones, 2020). This trapped residents in deprived neighborhoods with limited opportunities (Costa & De Valk, 2018; Obudho, 1997).

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The negative consequences of segregation are often exacerbated by weaknesses in formal urban planning systems and ineffective urban governance (Halfani, 1997). Besides, the most critical challenge lies in the absence of consensus on the most effective urban policies to target spatial inequalities, especially those arising in multi-ethnic segregation (Bolt, 2009). Some attribute this variation to the power dynamics faced by authorities, while others point to differing perspectives on the root causes of ethnic segregation. This disagreement makes it more difficult for policymakers to formulate effective and practical solutions.

The results of these weaknesses are undeniable. Widened wealth gaps, unequal distribution of resources and the formation of ethnically and socio-economically homogenous suburbs emerge (Nijman & Wei, 2020). On the other hand, developed nations witness the expansion of isolated ethnic or racial enclaves, characterized by unequal access to essential services like employment, healthcare, and basic amenities (UN-Habitat, 2022; Van Ham et al., 2018). Conversely, developing countries experience segregation compounded by the rapid proliferation of slums and impoverished areas juxtaposed against affluent neighborhoods (Messner, 2019).

The emergence of multi-ethnic segregation presents distinct social and economic challenges for cities (Benassi et al., 2023). This hinders progress towards sustainable development (Bansal, 2021). This is particularly concerning given the observed rise in both ethnic and wealth divides within cities (Gradín, 2019). Although the threat of spatial segregation is intensifying, viable solutions to counteract it are scarce.

The spatial patterns of ethnic segregation within cities takes diverse forms globally. In Dublin, Ireland, for example, segregation is driven largely by socio-economic factors (Fahey & Bryan, 2010), while Amsterdam confronts a situation where ethnicity and race are more prominent determinants of residential patterns (Deurloo & Musterd, 2001). In the United States, many downtown areas are characterized by concentrated Black and Hispanic populations, often referred to as "ghettos" (Zapatka et al., 2021; Archer, 2019; Massey & Denton, 1987). While Australian cities also exhibit ethnic dimensions in housing patterns, segregation is generally less severe compared to US ghettos (Pacione, 2009). Conversely, research on Canadian cities suggests a distinct trend, with rising income inequality emerging as a key driver of residential segregation (Townsend & Walker, 2002).

The experience of segregation in African cities is distinct, being strongly tied to their colonial past. During this era, residential and racial segregation policies were employed as a tool to restrict the freedom of indigenous Africans to choose their place of residence (Jimmy et al., 2020; Ren et al., 2020; Mwaniki, 2017; K'Akumu & Olima, 2007). Colonial powers used segregation to enhance political control and enforce social hierarchies. For instance, in Cape Town, South Africa, the city was racially divided between white and black residents, with wealthy, well-maintained districts having desirable amenities reserved for whites. These areas were juxtaposed against harsh and uninviting residential areas lacking green spaces and amenities, primarily designated for black residents (Turok et al., 2021).

In Nairobi, Kenya segregation stretches back to the early 1900s, well before Kenya gained independence. Colonial policies laid the foundation for this spatial division, creating a racially segregated city (Ren et al., 2020; K'Akumu & Olima, 2007). Founded in 1899 as a railway depot (Naji & Schildknecht, 2024), Nairobi's transformation into the capital of British East Africa in 1905 was accompanied by the imposition of racial segregation through land-use policies. The racial segregation can be attributed to the influence of early European settlers (Jimmy et al., 2020; Mwaniki, 2017). As a result, Nairobi experienced an ethnic tripartition, with Europeans predominantly inhabiting the high-end northwestern and western areas, Asians settling in the northeastern parts, and indigenous Africans being confined to densely populated regions in the eastern and southern areas of the city (Wanjiru-Mwita & Giraut, 2020; Obudho, 1997). European settlers were attracted by the fertile red soil of the hills where they established their exclusive enclaves in the highlands (van Oostrum, 2023; Achola, 2001).

The colonial spatial organization, structured along racial/ethnic lines, has had a lasting impact on Nairobi's development. While African settlements eventually grew towards the city center, the initial separation remained deeply ingrained, and the deliberate segregation extended beyond neighborhoods. Wealthy, low-density European enclaves in places like Gigiri, Westlands, and Nyari stood in clear contrast to the densely populated and flood-prone areas inhabited by Asian and African communities in Parklands, Highridge, and Ngara (Achola, 2001). Furthermore, Europeans seeking complete isolation established exclusive gated communities in Karen, Muthaiga, Upper Parklands, Westlands, Loresho, Kileleshwa, and Kilimani (Naji & Schildknecht, 2024; K'Akumu & Olima, 2007). In present-day, ethnic segregation based on the city's largest ethnic groups continues to persist in various forms. Additionally, residential areas continue to be segregated based on income status, creating disparities in the quality of place and quality of life for residents depending on their residential choices.

Nairobi's residential landscape has undergone significant transformation, characterized by increasing ethnic diversity and complexity. While ethnicity is intertwined

with politics and development, the spatial dimensions of ethnic segregation remain understudied. Existing research primarily focuses on historical racial segregation (Greenwood & Topiwala, 2020; Murunga, 2012), neglecting contemporary ethnic patterns in the city. Consequently, there is a limited understanding of the spatial distribution of ethnic groups, the emergence of ethnic segregation, and its associated implications.

These contrasting perspectives highlight the complex nature of segregation and the need for context-specific research. A notable gap exists in the literature on spatial segregation in both pre- and post-colonial Nairobi (van Oostrum, 2023; K'Akumu & Olima, 2007; Achola, 2001; Obudho, 1997; Ngau, 1979). To address this, this study aims to spatially map multi-ethnic segregation in Nairobi, focusing on the Kikuyu, Luo, Kamba, Kisii, and Luhya ethnic groups. By identifying patterns of segregation, the study seeks to inform the development of targeted interventions for intra-urban desegregation and provide a foundation for future research on the evolution of ethnic residential patterns in the city.

2 Study area

Nairobi City, the capital and largest city of Kenya by both population and area, spans an administrative area of approximately 696.1 km² (Nairobi City County, 2014). Over the past century, it has experienced exponential population growth, with its population rising from 8,000 in 1901 to 118,579 by 1948, and further increasing to an estimated 350,000 by 1963 (Obudho, 1997). Currently, the city's population is estimated at 4,397,073, with a density of 6,247 people per square kilometer (Kenya National Bureau of Statistics, 2019a), and it is projected to surpass 6,180,029 by 2045 (Kenya National Bureau of Statistics, 2019b). Although this rate of increase is still above the average national urban population growth rate of 3.7% p.a (UN-Habitat, 2023), Nairobi is likely to continue leading in terms of absolute population size. It is a culturally diverse and cosmopolitan metropolis, with its population primarily comprising Africans (95%), followed by Asians (4%), and Europeans making up around 1% (Nzau & Trillo, 2020). Among the African population, five major ethnic groups—Kikuyu, Luo, Kamba, Kisii, and Luhya—account for over 79% of Nairobi's residents (KNBS, 2019; Owuor & Mbatia, 2008).

Founded by the British in 1899 as a railway depot on the Mombasa-Uganda railway (Kimari & Ernstson, 2020), Nairobi lies at 1°17'31.44" S, 36°49'19.01" E, and about 140 km south of the equator (Nairobi City County, 2023). It borders Machakos, Kiambu, and Kajiado counties, and is divided into 17 constituencies and 85 wards (see Fig. 1). Since independence, Nairobi has become a key economic hub in East and Central Africa, contributing 50% of Kenya's formal employment and GDP (Nairobi City County, 2014). It hosts numerous Kenyan businesses and over 100 international organizations, including UNEP and UN-Habitat. The city also houses the Nairobi Stock Exchange, Africa's fourth-largest by trading volume (Okiro et al., 2019).

Over half of Nairobi's population reside in slums, which occupy 5% of the city's residential area (Kamau & Njiru, 2018; Archambault et al., 2012). These areas face severe economic inequalities, inadequate access to water, sanitation, and waste disposal (UN-Habitat, 2016). Nairobi's monetary poverty rate is 16.6%, while its multidimensional poverty rate is 12.6% (Nairobi City County, 2023).

Nairobi presents a compelling case study due to its vibrant yet segregated cityscape, making it crucial to understand the spatial patterns of ethnic groups within its boundaries. Like many other cities, Nairobi faces the challenges of ethnic segregation, with a distinct "East-West division" highlighting affluent and impoverished areas amongst different ethnicities (Nyamai & Schramm, 2023). The city's large multi-ethnic population necessitates an empirical understanding of the spatial patterns of ethnic segregation (Jones, 2020). Therefore, the study employed a case study approach, focusing on Nairobi City.

3 Data and methodology

3.1 Data

This study focused on the five largest ethnic groups in Nairobi—Kikuyu, Luhya, Kisii, Luo, and Kamba—which collectively constitute approximately 79% of the city's population (KNBS, 2019). To examine the spatial patterns of segregation among these groups, we utilized a 10% sample from the 2019 Kenya Population and Housing Census (KNBS). This sample, comprising 435,388 households, provides a robust dataset for our analysis. While the census offers comprehensive demographic data, the study concentrates on the five primary ethnic groups, accounting for 346,793 individuals. It's important to note that unlike traditional notions of race, ethnicity remains a significant factor influencing residential patterns in Nairobi. The 10% sample size strikes a balance between data representativeness and computational efficiency, enabling rigorous spatial and statistical analysis.

3.2 Method

3.2.1 Measuring segregation using the index of dissimilarity

The Index of Dissimilarity (ID) is a widely used metric for quantifying the spatial separation of different social groups within a defined geographic area, such as cities, neighborhoods, or regions (Massey & Denton, 1987; Pacione, 2009). Essentially, it quantifies the level of segregation by comparing the actual distribution of groups

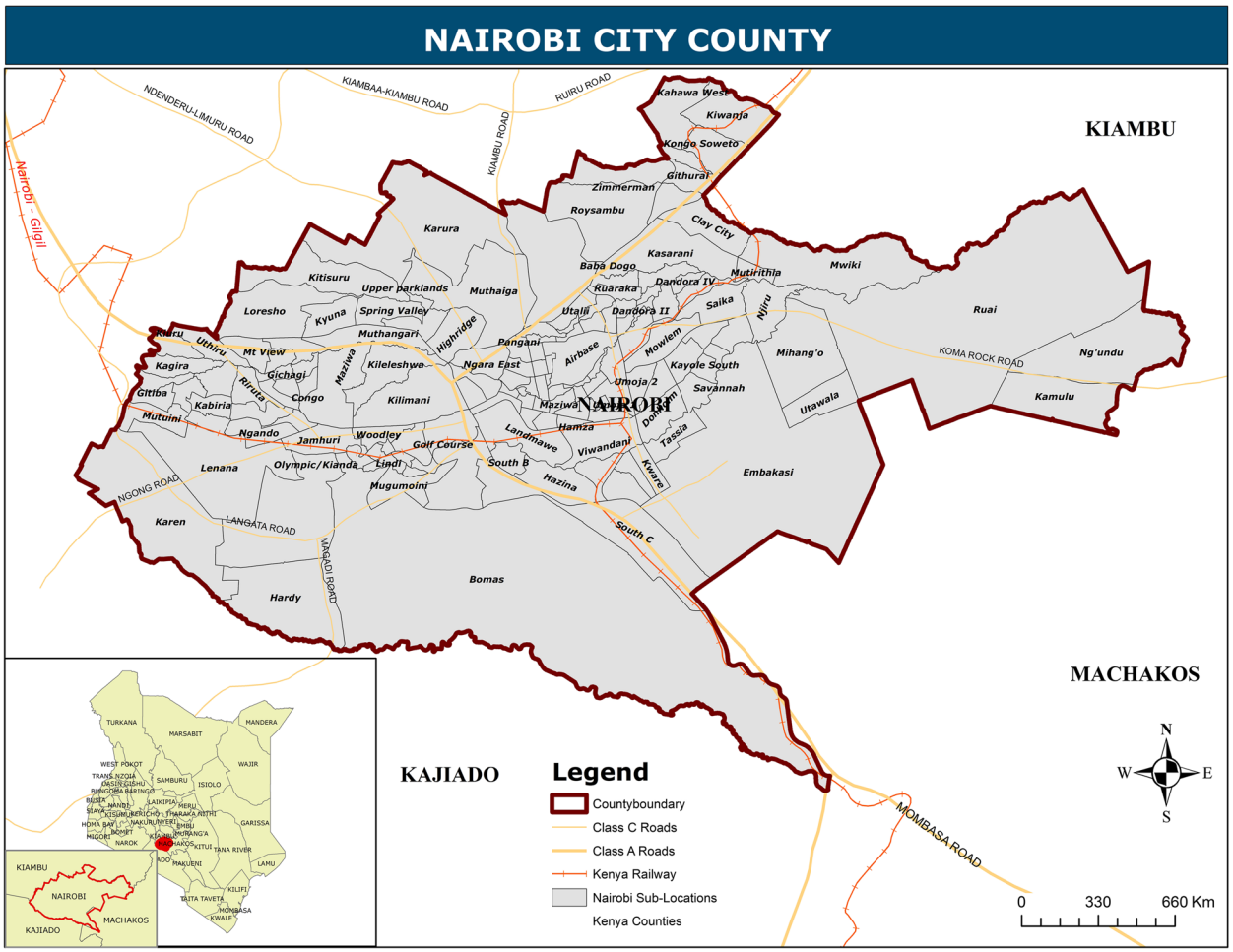

Fig. 1 Study area

with an ideal scenario of complete integration.(Pacione, 2009; Huie, 2000; Massey & Denton, 1988). Calculating the ID involves a three-step process: step one quantifies proportions whereby the proportion of each group within each geographic unit (e.g., ward, census block) is determined. In step 2, the disparity is measured whereby the difference between the actual group proportions and the expected proportions under perfect integration is calculated for each unit. Lastly, these disparities are summed across all units, resulting in the overall ID. A higher ID value indicates a greater level of segregation, reflecting a larger hypothetical relocation of members from one group to achieve integration. Pacione (2009) describes the ID as a measure of "the net fraction of one population who would have to move" to create a blended community. The ID, as a measure of segregation has been widely used by researchers because of its consistency when analysed with available census data over a certain period of time; and for the ease at which it can be used to compare by analyzing segregation levels across different ethnicities (Popescu et al., 2018; Boustan, 2013). The ID was chosen as the primary measure of spatial evenness in this study due to its well-established methodological strengths. The ID has a long history of application in segregation research, supported by extensive research, and offers advantages in both ease of interpretation and computational simplicity (Massey & Denton, 1987, 1988).

The ID, like many metrics, has limitations. One key concern is its sensitivity to scale. Segregation levels measured by the ID can vary depending on the chosen geographic unit of analysis (Pacione, 2009). This highlights the importance of carefully selecting the spatial unit to minimize the impact of the Modifiable Areal Unit Problem (MAUP). MAUP refers to the well-documented phenomenon where the choice of geographic units of analysis (e.g., census tracts, neighborhoods) can significantly influence the observed patterns and interpretations of spatial data (Javanmard et al., 2023; Chen et al., 2022; Duque et al., 2018; Nthiwa, 2011). To mitigate MAUP, this study employed location-level data analysis.

This approach is crucial for ensuring robust and reliable research findings, allowing for accurate interpretation and comparison of spatial and statistical data.

Furthermore, the ID itself does not provide insights into the root causes or specific spatial patterns of segregation within complex urban environments (Huie, 2000). While the ID is a valuable tool for quantifying segregation, its effective use necessitates careful interpretation and awareness of its limitations. Critical consideration of scale, MAUP, and the need for additional contextual data is paramount to drawing accurate and informed conclusions about spatial inequalities.

In this study, we calculated the ID to assess the spatial segregation between the five main ethnic grouping in Nairobi at the city and location level. The ID was computed using Geo-Segregation analyzer and statistical software STATA version 16.1.

We used the Eq. 1 below to calculate the ID (Massey & Denton, 1988).

$$\mathbf{D} = \sum \mathbf{n}_{\mathbf{i}-1}[\mathbf{t_i}|\mathbf{P_i} - \mathbf{P}|/2\mathbf{TP}(1-\mathbf{P})] \quad (1)$$

Equation 1: For calculating ID Where t_i and p_i are the total population and minority proportion of areal unit I, and T and P are the population size and minority proportion of the whole city, which is subdivided into n areal units. The ID measures departure from evenness by using the weighted mean absolute deviation of every units minority proportion from the city's minority proportion and expressing this quantity as a proportion of its theoretical maximum (James and Taeuber, 1985 in Massey & Denton, 1988). Values for the ID ranges from 0 to 1. A measure of 1 indicates that the city is completely segregated (i.e., maximum dissimilarity) and neighbourhoods are inhabited exclusively by one group. On the other hand, a measure of 0 would show that the two groups being studied are evenly distributed or no dissimilarity.

3.2.2 Mapping the spatial pattern of segregation using GIS anselin local Moran's I

We leveraged data from the 2019 KNBS population and housing census to define neighborhood boundaries within the study area. Socio-economic and spatial data were then disaggregated to the location level, enabling an analysis of spatial segregation patterns. We used Cluster and Outlier Analysis (Anselin Local Moran's I) in ArcGIS 10.8's Spatial Statistics toolbox to identify statistically significant clusters of neighborhoods with similar ethnic characteristics. The method revealed not only the presence of clusters but also their dispersion patterns, allowing for the grouping of neighborhoods based on shared attributes. Importantly, this analysis helped determine the optimal scale for further spatial analysis and exploration of spatial relationships.

To assess spatial patterns of ethnic segregation, we employed Anselin Local Moran's I (Mitchell, 2005). Unlike traditional non-spatial statistics, Anselin Local Moran's I was employed due to its ability to explicitly account for spatial relationships such as proximity and area. As a specialized tool for analyzing patterns within spatial and socio-economic data (ESRI, 2020), Anselin Local Moran's I was pivotal in identifying statistically significant clusters or dispersions of similar ethnic populations across neighboring geographic units. It does this while accounting for potential bias caused by variations in neighborhood sizes (using row standardization). Anselin Local Moran's I is a spatial geostatistical method that is used to assess the presence of localized spatial autocorrelation and to map spatial clusters or outliers. It does this by classifying the statistical significance of Z-values and p-values into hot spots of High-High clusters, High-Low clusters, cold spots of Low-High clusters, Low-Low clusters or statistically non-significant areas at $p<0.01$ or $p<0.05$. The analysis yields Z-scores (LMiZScore) and p-values (LMiPValue), which indicate the statistical significance of the observed patterns (Mathenge et al., 2022; Nkamwesiga et al., 2022). LMiIndex provides information about the intensity of clustering, while COType highlights the type of spatial pattern observed. Positive Moran's I value signal clustering of similar ethnic groups, whereas negative values suggest dispersion.

4 Results

4.1 Results of the extent of multi-ethnic spatial segregation in Nairobi City

The statistics presented in Table 1 offers a breakdown of Nairobi's ethnic composition based on the tabulation of

Table 1 Nairobi County's ethnicity crosstabulation

		Ethnicity					Total
		Kamba	*Luo*	*Kisii*	*Kikuyu*	*Luhya*	
Nairobi City	Population	64,512	66,445	28,980	117,555	69,301	346,793
	%	18.6%	19.2%	8.4%	33.9%	20%	100%

Source: KNBS, 2019 Housing and Population census

the five largest ethnic groups. The *Kikuyu* ethnicity forms the largest segment, comprising 33.9% of the total population. The *Luhyia* ethnic group comes next, representing 20% of residents. The *Luo* follows closely, making up 19.2% of Nairobi's population, while the *Kamba* ethnicity constitutes 18.6%. The *Kisii* ethnic group comprises the smallest percentage at 8.4%, but still contributes significantly to Nairobi's overall diversity.

The ID (Table 2; Fig. 2) between *Kamba* and *Luo* ethnic groups (0.3610), suggests that a low level of dissimilarity exists between them. In other words, approximately 36.10% of individuals from either group would need to relocate in order to achieve perfect integration. These findings highlight a relative degree of residential segregation between the *Kamba* and *Luo* communities, indicating that they tend to reside in separate geographic areas in Nairobi. Conversely, the dissimilarity between the *Kamba* and *Kisii* ethnic groups (0.2679) is comparatively lower. This suggests the presence of a low level of spatial mixing or integration between these two groups. About 26.79% of individuals would need to relocate for the groups to be perfectly integrated. This suggests that *Kamba* and *Kisii* communities are relatively more intermingled across Nairobi City compared to the *Kamba-Luo* dynamic.

Table 2 ID between *Kamba*, *Luo*, *Kisii*, *Kikuyu* and *Luhyia* at City level

Name	Kamba	Luo	Kisii	Kikuyu	Luhyia
Kamba		0.3610	0.2679	0.3978	0.3109
Luo	0.3610		0.3850	**0.4162**	0.2778
Kisii	0.2679	0.3850		**0.4075**	0.2834
Kikuyu	0.3978	**0.4162**	**0.4075**		**0.4034**
Luhyia	0.3109	0.2778	0.2834	**0.4034**	

NB, Those in bold show a higher level of dissimilarity

The ID between *Kamba* and *Kikuyu* (0.3978), indicates a low level of dissimilarity. Roughly, 39.78% of individuals would need to relocate for perfect integration, highlighting a significant level of residential segregation between these groups. Similarly, the *Kamba* and *Luhyia* ethnic groups show a moderate level of dissimilarity (0.3109). Around 31.09% of individuals from either group would need to move for perfect integration, suggesting a low level of residential segregation between them, which is similar to the *Kamba-Luo* dissimilarity. There are distinct areas in Nairobi City where each group is more concentrated.

The findings from ID between *Luo* and *Kisii* (0.3850) shows a moderate low level of dissimilarity between them. Approximately 38.50% of individuals from either group would need to relocate to achieve perfect similarity. This suggests that while the *Luo* and *Kisii* communities are not completely segregated, there are noticeable differences in their residential patterns within the region. The moderate dissimilarity value might stem from historical or geographical factors that have influenced their settlement patterns.

At the same time, the ID between *Luo* and *Kikuyu* (0.4162) ethnic groups, shows the highest level of dissimilarity observed compared to all other IDs for all ethnic crosstabulations. This means that, about 41.62% of individuals from either group would need to move for perfect integration to be achieved in Nairobi City. This higher level of dissimilarity indicates that the *Luo* and *Kikuyu* communities are more spatially separated from

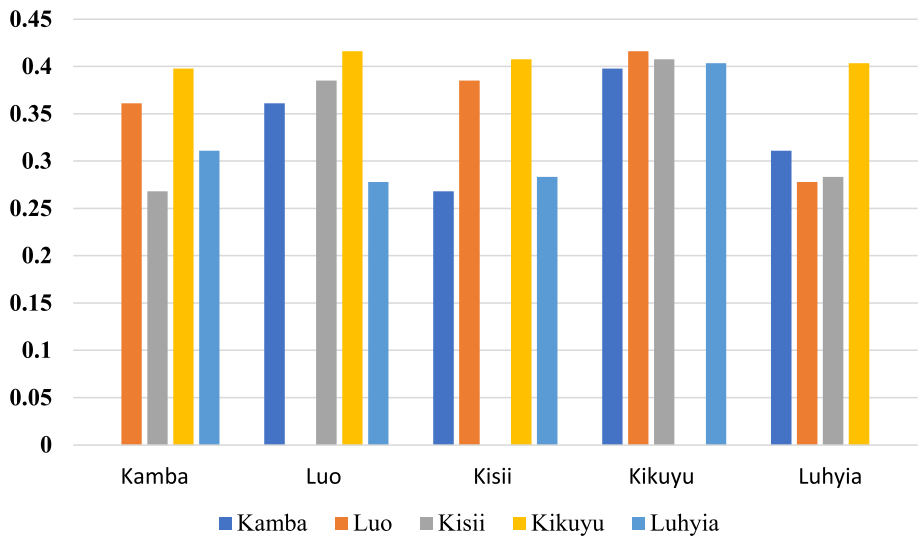

Fig. 2 ID between *Kamba*, *Luo*, *Kisii*, *Kikuyu* and *Luhyia* at City level

each other within Nairobi City. The political landscape in Kenya could explain these dynamics, according to an expert:

> *"This might be due to a variety of factors, such as cultural differences or localized settlement patterns due to the prevailing political affiliations between the Kikuyu and the Luo nations that have contributed to their distinct residential areas" (KII).*

However, the dissimilarity between the *Luo* and *Luhyia* ethnic groups is low, with an ID of 0.2778. This suggests a less segregated residential pattern between these groups, with approximately 27.78% of individuals needing to move for perfect spatial mix. These two groups are relatively close to each other but not to the extent of complete similarity. An expert observed that:

> *"Culturally, the Luo and the Luhyia have shared common cultural practices, names and geographical borders and historically have been affiliated to the same political persuasions for a long time" (KII).*

The calculated ID value (0.4075) between the *Kisii* and *Kikuyu* ethnic groups suggests a high level of dissimilarity between them. Roughly 40.75% of individuals from either the *Kisii* or *Kikuyu* group would need to relocate to avert segregation. This finding indicates a significant degree of residential segregation between the two groups. The higher ID value underlines the distinct geographic areas where the *Kisii* and *Kikuyu* communities tend to reside, with limited overlap. Equally, the ID value (0.4034) between the *Kikuyu* and *Luhyia* ethnic groups reflects a higher level of dissimilarity, similar to the *Kisii-Kikuyu* dissimilarity. Around 40.34% of individuals from either the *Kikuyu* or *Luhyia* group would need to move for perfect integration to be achieved between them. This indicates that the *Kikuyu* and *Luhyia* populations are also more segregated from each other within the studied area. Just like with the *Kisii-Kikuyu* patterns, the higher ID value underscores the distinct residential patterns of the *Kikuyu* and *Luhyia* communities, pointing to historical, cultural, or socio-economic factors that may have contributed to their spatial separation.

Lastly, the dissimilarity between the *Kisii* and *Luhyia* ethnic groups is relatively lower, with an ID of 0.2834. This suggests a less segregated residential pattern between these groups, with approximately 28.34% of individuals needing to relocate for perfect integration. This implies some degree of mixing or integration between these groups. These findings provide evidence of varying levels of residential segregation between different ethnic groups at the city scale in Nairobi. The results highlight the concentration of individuals from specific ethnic backgrounds in particular areas and suggest the presence of social, cultural, and historical factors that contribute to these segregation patterns.

4.2 The spatial patterns of ethnic segregation in Nairobi City

The results of the cluster and outlier analysis using Anselin's Local Moran's I shown in Fig. 3a-e below demonstrated significant spatial patterns of the five main ethnic groupings in Nairobi. Positive Z-scores greater than 1.96 (at 0.05, 0.01 and 0.1 confidence levels) and negative Z-scores less than −1.96 indicated statistically significant spatial clustering or dispersion for each ethnicity. Based on this, we therefore rejected our null hypothesis as the observed spatial patterns could not be attributed to randomness in the data.

The occurrence of High-High (HH) Clusters demonstrated that there was significant positive spatial autocorrelation for *Kamba* in Embakasi, Tassia, Kware, Mukuru Kwa Njenga, Imara Daima, Kwa Reuben, Donholm, Umoja 2, Viwandani and Hazina. This implies that some neighbourhoods with a high presence of *Kamba* tended to be surrounded by neighborhoods with similarly high concentrations of *Kamba* and hence the existence of clusters dominated by the *Kamba* in Nairobi City. Low-low (LL) clusters suggests that Ngando, Gitiba, Mutuini, Kagira, Ruthimitu, Kiuru, Uthiru, Mukarara, Waithaka, Majengo, Makina, Jamhuri, Woodley, Karen, Lenana, Lang'ata, Kamukunji, Ngara East, Ngara West, City Centre, Racecourse, Pangani,

Highridge, Karura, Muthaiga, Spring Valley, Upper parklands, Kitisuru, Kilimani and City Square are neighborhoods with minimal *Kamba* presence. On the other hand, a significant negative spatial autocorrelation (LL cluster) indicated that neighbourhoods with a low presence of *Kamba* were surrounded by neighborhoods with similarly low concentrations of *Kamba*. This signifies the presence of clusters or locations where *Kamba* are less prevalent in Nairobi City.

All the areas that were shown as non-significant areas and with values close to zero e.g. Hamza for *Kisii* (LMi-Index = 0.020, Z Score = 0.087 and $p > 0.05$) or Jericho/Lumumba for *Kikuyu* (Index = −0.0090, Z Score = −0.0536 and $p > 0.5$) were not statistically significant and indicated a lack of significant spatial autocorrelation. This implied a more random distribution of the specific ethnicity across the city.

Spatial cluster and outlier analysis identified regions where the concentration of a specific ethnicity was significantly higher or lower compared to neighboring locations (Fig. 3: a-e). This served as an indicator of areas deviating from the norm in terms of ethnic composition.

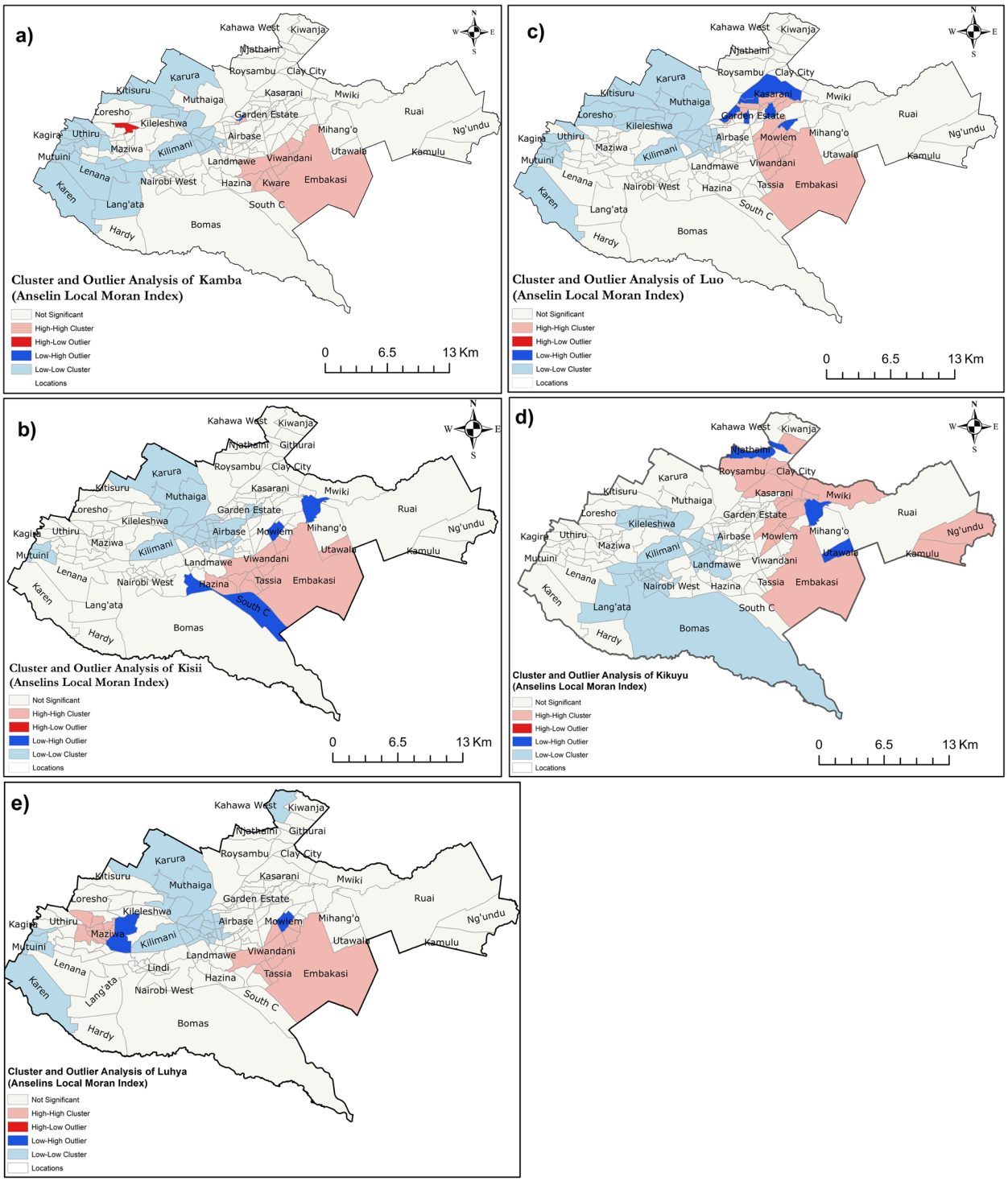

Fig. 3 **a-e**: Anselin Local Moran I for *Kamba*, *Luo*, *Kisii*, *Kikuyu* and *Luhyia*

For instance, High-Low Outliers (HL) in Kangemi Central (Index = −0.180, Z Score = −0.994, at a significance level of, $p < 0.05$) for *Kamba* shows that Kangemi Central has a significantly higher concentration of *Kamba* compared to their neighboring locations. This implies that Kangemi Central is characterized by unique socio-cultural factors, historical developments, migration patterns, or economic opportunities that have led to a

higher concentration of the *Kamba* in the neighbourhoods within.

Likewise, Low-High Outliers (LH) for *Luhyia* in Maziwa (LMi Index = −0.342, Z Score = −2.048 and $p < 0.05$), *Kikuyu* in Utawala (Index =−0.3873, Z Score = −3.1042 and $p < 0.05$), and *Luo* in Komarock North (Index = −0.353, Z Score = −2.94 and $p = 0.01$) (Fig. 3) represents locations with a low value surrounded by high values of a particular ethnicity. This indicates instances of integration or assimilation where members of *Luhyia*, *Kikuyu* and *Luo respectively* are living within areas predominantly occupied by other ethnicities.

5 Discussion

5.1 Interpretation of results

By employing Anselin's Local Moran's I analysis to examine the spatial patterns of the *Kamba*, *Kikuyu*, *Luo*, *Luhya*, and *Kisii* ethnicities in Nairobi, we gained insights into the spatial clusters and outliers within the city. We were able to understand the spatial distribution of the different ethnic groups within the city and the extent of their spatial segregation. *Kamba* were seen to cluster in areas such as Embakasi, Tassia, Mukuru Nyayo and Umoja and *Kikuyu* in Kahawa West, Zimmerman, Roysambu, Kasarani and Mwiki. The *Luo* showed significant clustering in areas such as Kariobangi, Lucky Summer, Kayole, Komarock, Kibera, Mathare, and Korogocho while Luhya exhibited concentrations in locations like Kangemi and Kawangware with *Kisii* dominating Utawala, Savannah and Viwandani among others.

This study demonstrates the spatial clustering of specific ethnic groups within Nairobi. This finding aligns with other research documenting similar patterns of ethnic concentration in other urban areas. As Sarwari and Ono (2023) observed in Kabul City, new city residents often gravitate towards neighborhoods with established co-ethnic communities. This preference can be attributed to shared cultural heritage, language, and social connections that foster a sense of belonging.

This observed pattern likely arises from a complex interplay of historical legacies, cultural dynamics, and economic opportunities associated with each ethnicity (Bocquier et al., 2009). Achola (2001) notes that ethnic concentration often intertwines with socio-economic disparities in Nairobi. Historical settlement patterns and resource allocation during the colonial era (Obudho, 1997) contribute to this spatial distribution. This resonates with Greenwood and Topiwala (2020) where the spatial distribution of different races/ethnicities in Nairobi was a function of colonial segregationist policies. Furthermore, contemporary economic inequalities lead to affluent areas attracting specific ethnicities, while poorer areas remain more diverse (Jimmy et al., 2020). Additionally, the desire for co-ethnic residence fosters clustering, as shared traditions, language, and social networks creates a sense of belonging and community. This phenomenon, documented among Black households in the US (Boustan, 2013; Charles, 2003; Massey, 1990), persists in Nairobi despite post-colonial policy changes.

Additionally, the ID proved to be an effective tool in identifying spatial patterns of segregation among Nairobi's five major ethnic groups: Kikuyu, Luo, Kamba, Kisii, and Luhya. This approach pinpointed the most segregation locations, creating opportunities for targeted interventions and area-based policy measures. This targeted approach is crucial to prevent further ethnic-based social divisions. As highlighted by Ajulu (2002), ethnic segregation among these groups can reinforce social divisions and limit integration. This can potentially lead to social unrest (Haandrikman et al., 2023; Van Stapele, 2015).

Our findings reveal pronounced ethnic segregation among major ethnic groups in Nairobi, with consequential disparities in access to services and neighborhood quality for affected populations. This pattern is echoed in other global cities. For instance, Dakar, Senegal, experienced deliberate ethnic segregation under French colonial rule (Njoh, 2017). While US cities have historically exhibited extreme spatial segregation of marginalized ethnic minorities in urban ghettos, recent trends suggest a shift. Zapatka et al. (2021) reported a decline in white households in cities like New York and Newark. However, although racial and ethnic disparities in housing exist in places like Brazil and Australia, they are less pronounced than the stark segregation observed in US cities (Carvalho & Netto, 2023; Azpitarte et al., 2021; Leibbrand et al., 2020). At the same time, research consistently links ethnic segregation to access to services and neighborhood selection. Studies from Brazil, South Africa, Estonia, Belgium, and England and Wales corroborate this association (Carvalho & Netto, 2023; Järv et al., 2021; Gradín, 2019; Costa & De Valk, 2018; Harris et al., 2017).

The ID's findings underscore the need for policymakers and researchers to design strategies that promote inter-ethnic integration, foster coexistence, and build social cohesion within Nairobi's diverse communities. These findings resonate with Fung-Loy and Van Rompaey (2021), research in Suriname, where the ID identified Maroons and Javanese as the most segregated ethnicities. Their work underscores the importance of desegregation policies that aim to increase ethnic mixing and reduce socio-economic disparities. However, research by Tan (2023) in Singapore suggests that ethnic desegregation policies, while successful in some contexts, may not universally address rising socio-economic segregation.

The spatial distribution of ethnicities in Fig. 3a-e show segregation patterns. These mixed-ethnicity neighborhoods might exhibit distinct demographic characteristics and cultural dynamics compared to homogenous areas. This finding aligns with Bocquier et al. (2009) who established a correlation between ethnicity, language, and assimilation patterns within Nairobi. Furthermore, K'Akumu and Olima (2007) highlight the historical underpinnings of this segregation, potentially rooted in colonial land policies. Their work suggests opportunities for intervention through robust and transformative policies aimed at promoting integration. Building on this, Ponzo (2010) emphasizes the value of learning from successful models like England's strong community cohesion policies and anti-racist/ethnic equality legislation. However, Baud et al.,(2009) offer a crucial caveat, stressing the importance of understanding the historical and spatial distribution of these inequalities for policymakers and urban planners to design effective interventions.

5.2 Consequences of ethnic segregation

The consequences of ethnic segregation are detrimental, fostering societal divisions and limiting access to resources and quality of life for marginalized communities (Jimmy et al., 2020; Costa & De Valk, 2018). Our findings reveal a stark ethnic divide in Nairobi City, rooted in its colonial legacy. British colonial authorities instituted a system of ethnic tripartition through urban planning and spatial control (Jimmy et al., 2020; Mwaniki, 2017), marginalizing the African population despite their crucial role in the economy. Post-independence, rapid urbanization exacerbated this divide, forcing Africans into underserviced areas that evolved into slums (Wanjiru-Mwita & Giraut, 2020; Obudho, 1997).

This study confirms the persistence of heavily segregated neighborhoods in Nairobi, leading to significant disparities in quality of life. As Jones (2020) argues, the enduring legacy of colonial spatial planning perpetuates inequality and marginalization. Coupled with growing inequality, ethnic segregation traps minorities and migrants in deprived areas, eroding social cohesion and limiting opportunities (Costa & De Valk, 2018).

Our research demonstrates that Nairobi's five largest ethnic groups—Kikuyu, Luo, Luhya, Kamba, and Kisii—exhibit concentrated residential patterns stemming from historical discrimination and economic disparities (Ajulu, 2002). This segregation fosters ethnic enclaves, hindering social integration and cultural exchange (Charles, 2003). The clustering of disadvantaged populations in specific neighborhoods exacerbates social and economic challenges, hindering civic participation, employment, and education, and potentially fueling social unrest (Haandrikman et al., 2023). The 2007/8 post-election violence in Kibera and Mathare slums underscores the dangerous consequences of these deep-rooted divisions (Van Stapele, 2015). Additionally, as noted by K'Akumu and Olima (2007), segregation presents significant challenges for effective urban planning and governance. Therefore, context-specific strategies are needed to promote integration and social cohesion within Nairobi (Mwaniki, 2017). This is critical considering the potential risks to national identity, unity, and development, as outlined in Kenya's national goals (Republic of Kenya, 2008). As such, utilizing ID and cluster analysis to grasp the nature and extent of segregation can aid policy makers to identify areas that require area-based spatial interventions for integrated, equitable communities.

5.3 Policy implications

Policy solutions for segregation can be categorized as: place-based (enhancing minority neighborhoods or mandating affordable housing in affluent areas), people-based (supporting homeowners/renters through fair housing enforcement or improved mortgage access), or indirect (addressing segregation symptoms like improving public transportation in isolated suburbs (Van Ham et al., 2018; Boustan, 2013). Therefore, for Nairobi, spatial integration policies promoting mixed-use developments (Smets & Salman, 2008) are needed. These developments, integrating residences, businesses, and schools, foster social cohesion and economic opportunity across socioeconomic groups. However, Van Ham et al. (2018) emphasize education as the most impactful tool for reducing inequality. Additionally, slum rehabilitation schemes (Nijman, 2008), affordable housing programs, skills development initiatives, and social infrastructure projects could mitigate segregation. A similar observation was made in Bengaluru, by Roy et al. (2018) that successful slum interventions for each of the segregated groups improved their living standards.

In addition, effective urban planning, supported by a robust housing policy framework is required (Sylvie & Frouillou, 2023; Abolghasem Rasouli, 2021; Smets & Salman, 2008; Obudho, 1997). This is considered key for a fair distribution of resources and services. However, Bolt (2009), argue that housing policies exhibit limited efficacy in influencing ethnic concentration due to their frequent contradictions and failure to address the primary causes of segregation.

The Nairobi City Government should prioritize these policy solutions by integrating robust planning frameworks into its transformation agenda. However, acknowledging the complexity is essential. Mathenge (2022) highlights challenges in implementing a multitude of national and county-level urban planning and development laws and policies due to conflicting timelines,

diverse spatial and sectoral focuses, and fragmented legal frameworks. By acknowledging these complexities and adopting a multi-faceted approach, policymakers can create a more inclusive and cohesive Nairobi for all residents.

5.4 Limitations and future research directions

This study has provided valuable insights into the spatial aspects of ethnic segregation in Nairobi City, utilizing the ID to analyze patterns among the five largest ethnic groups. While these methods were appropriate to achieve our research objectives, future research should expand beyond residential segregation to fully grasp the multi-faceted nature of ethnic dynamics. Further, in order to deepen our understanding of the factors influencing segregation and integration patterns, future research should consider methodological approaches, such as multilevel modeling, that incorporate hierarchical data structures to analyze the interplay between individual-level patterns and ecological factors. This should also explore the underlying social, economic, and historical forces in depth. This approach would not only improve spatial models but also provide a richer understanding of the complex dimensions of ethnic segregation, moving beyond quantitative (ID) and spatial autocorrelation metrics (Anselin Local Moran's I) to reveal the personal experiences of those affected. Additionally, due to the unavailability of 2009 ethnicity data from the Kenya National Bureau of Statistics, this study adopted a cross-sectional approach, examining Nairobi City neighborhoods using the most recently available data linked to GIS at the location level (2019). Given the absence of comparable ethnicity and spatial data for previous years (1988, 1999, and 2009), this study was not premised on assessing temporal changes in ethnic segregation or neighborhood characteristics. Such analyses will be the focus of future research, building upon the foundational insights of this study. It is anticipated that subsequent studies will measure evolving patterns of ethnic segregation among the five largest ethnic groups for comparison with the present findings.

6 Conclusion

This study has revealed the intricate patterns of ethnic segregation within Nairobi. By mapping the spatial distribution of the city's five largest ethnic groups – Kamba, Luo, Kisii, Kikuyu, and Luhyia – we have shown the realities of ethnic segregation and offered crucial insights for policymakers and urban planners. Our analysis, employing the ID and Anselin's Local Moran's I, has proven its effectiveness in pinpointing areas of concentrated segregation and highlighting potential sources of social exclusion. This understanding enables targeted spatial interventions, tailoring policy and planning initiatives to specific neighborhoods and communities experiencing the most acute disunity. The identified hotspots of segregation necessitate proactive measures to foster integration and coexistence. Urban policy interventions like fair housing laws, affordable housing programs, and initiatives addressing systemic racism and ethnicity can pave the way for more equitable neighborhoods (Baud et al.,(2009). As Boustan (2013), Darden et al. (2018), and Popescu et al. (2018) emphasize, effectively addressing the multifaceted consequences of segregation necessitates a comprehensive approach. This approach should prioritize fostering social cohesion and inclusivity within communities.

However, navigating Nairobi's segregated landscape requires acknowledging its complex historical roots. Pacione (2009) noted that urban segregation often originates from power imbalances within the real estate market, highlighting the need for policies sensitive to unique historical, political, and social dynamics. Moving forward, sound urban policies, especially spatially targeted interventions aimed at empowering marginalized communities, become paramount. In conclusion, this study transcends mere mapping; it highlights a roadmap for transforming Nairobi's segregated landscape. By embracing the interplay of historical, social, political, and geographic factors shaping the city's ethnic landscape, urban policymakers can pave the way for a more integrated and equitable future for all Nairobians. Achieving cohesive cities demands a collaborative, multi-disciplinary and collective commitment to addressing segregation and fostering a sense of shared belonging.

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Authors' contributions

Alex Nthiwa developed the proposed concept, conducted a review of the existing literature, performed computations and GIS analysis, validated the analytical methods, and discussed the results. Leonard Kisovi, Thomas Kibutu, and Philomena Muiruri supervised the data collection, findings of this research and reviewed the final manuscript.

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Data availability

Datasets and analysis results tables are accessible via Zenodo at DOI https://doi.org/10.5281/zenodo.11080309.

Declarations

Ethics approval and consent to participate

This work was approved by the National Commission for Science, Technology and Innovation of the Republic of Kenya vide letter reference NACOSTI/P/16/71188/8986.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests or conflicts of interest with respect to the research, authorship or publication of this article.

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