Evaluating the Challenges of Municipal Governance in Managing Urban Sprawl: A GIS-Based Assessment of the Kaduwela Municipal Council, Sri Lanka

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Abstract

Urban sprawl presents multifaceted governance challenges in rapidly urbanizing regions, such as the Kaduwela Municipal Council (KMC) area in Sri Lanka. This study investigates the spatial dynamics and governance implications of urban expansion over the 2004–2024 period, employing Geographic Information System (GIS) tools and Landsat satellite imagery. It analyses land use transitions, including the expansion of built-up areas and the consequent reduction of agricultural lands, wetlands, and vegetative cover. These spatial assessments are complemented by municipal records and socio-economic data to provide a comprehensive perspective on urban transformation. The findings reveal substantial unplanned land conversion, resulting in environmental degradation, infrastructural stress, and regulatory shortcomings. Furthermore, socio-economic factors, such as escalating property values and disparities in access to public services, intensify the governance burden. In response, the study advocates for integrated planning approaches underpinned by GIS-based monitoring systems to enable real-time land use assessment. Key policy recommendations include the reinforcement of zoning regulations, the promotion of sustainable land use practices, and the enhancement of governance capacities through smart technologies and inclusive stakeholder engagement. This research offers a data-driven framework to support policymakers and urban planners in addressing the challenges of urban sprawl and fostering resilient, equitable urban development.

Keywords: Urban sprawl, Governance challenges, GIS (Geographic Information System), Sustainable urban planning

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Introduction

Background

Rapid demographic and spatial transformations are reshaping Sri Lanka's urban landscape, with significant implications for municipal governance and sustainable development. As of 2025, Sri Lanka's population is estimated at 23.2 million, with a population density of 370 people per square kilometre and a median age of 33.3 years (Worldometer, 2025; Department of Census and Statistics, 2025). Although official statistics report that only 18.1% (Department of Census and Statistics, Sri Lanka 2024) of the population resides in urban areas, recent research suggests this figure underrepresents the true extent of urbanization and urban sprawl, particularly in peripheral municipalities such as Kaduwela (SDG Data Portal, 2025). Urban sprawl in Sri Lanka is characterized by unregulated expansion beyond designated city boundaries, resulting in challenges related to transportation, housing, waste management, and environmental sustainability (SDG Data Portal, 2025). These unplanned developments increase vulnerability to climate change and disaster risks, while also straining municipal resources and infrastructure (Baltic Journal of Real Estate Economics and Construction Management, 2025). The demand for urban utilities, such as water, electricity, and waste disposal, is projected to grow rapidly, intensifying the need for effective spatial planning and governance (Sri Lanka Sustainable Housing and Construction Roadmap, 2022). In this context, municipal councils like Kaduwela face mounting challenges in managing urban growth, ensuring equitable access to services, and promoting resilient, inclusive urban environments. Understanding these dynamics through GIS-based assessment is essential for evidence-based policy and sustainable urban management.

Research Problem

Urban sprawl presents significant challenges for municipal governance, particularly regarding sustainable land use, infrastructure development, and service delivery in rapidly expanding cities. In the context of the Kaduwela Municipal Council, Sri Lanka, the lack of effective spatial planning and coordinated management has intensified issues such as environmental degradation, inefficient resource allocation, and social disparities. These challenges necessitate a comprehensive assessment using Geographic Information Systems (GIS) to evaluate governance strategies and spatial patterns. It is imperative that these challenges are addressed in order to develop data-driven policies that support equitable urban development and improve living standards for urban residence

Objectives of the Study

The primary objective of this study is to critically evaluate the challenges faced by municipal governance in managing urban sprawl within the Kaduwela Municipal Council area in Sri Lanka. It aims to analyse the spatial and temporal patterns of urban expansion from 2002 to 2024 using Geographic Information System (GIS) and remote sensing technologies. The research seeks to assess changes in land use and land cover, focusing on the increase in built-up areas and the corresponding decline in vegetation and water bodies. By integrating geospatial data with qualitative insights drawn from municipal records and stakeholder perspectives, the study endeavours to understand the governance implications of rapid urbanization. Ultimately, the objective is to provide evidence-based recommendations that support sustainable urban management, promote balanced development, and strengthen decision-making processes through the application of advanced GIS-based tools and spatial analysis.

Research Questions

The present study proposes a series of inquiries to methodically investigate the obstacles encountered by municipal authorities in addressing urban sprawl within the Kaduwela Municipal Council area. The central inquiries of this study concentrate on the identification of the spatial and temporal trends of urban growth in Kaduwela. In addition, they examine the socio-economic and environmental consequences of such expansion. Furthermore, they evaluate the potential of GIS-based analysis to support informed decision-making for sustainable urban governance. The objective of the present study is to utilise the aforementioned questions to produce data-driven insights that contribute to effective policy formulation and urban planning, to achieve balanced and resilient development.

Significance of the Study

This research is significant as it offers data-driven insights into the impacts of urban sprawl on municipal governance and sustainable development within the Kaduwela area of Sri Lanka. Utilizing GIS-based analysis, the study tackles key deficiencies in spatial planning, resource management, and the provision of public services. Its outcomes are intended to guide policymakers and urban planners in designing focused strategies to control urban expansion and reduce adverse effects on land use, infrastructure systems, and environmental integrity

Scope and Limitations

This study investigates land use transformations and governance issues associated with urban sprawl in the Kaduwela Municipal Council area, using GIS and remote sensing tools for spatial analysis. It draws on primary data collected through fieldwork alongside secondary information obtained from relevant institutions. However, the research faces certain limitations, including possible data inconsistencies, challenges in merging data from multiple disciplines, and a limited time frame, which may constrain the broader applicability of the results to other urban regions.

Literature Review

Urban Sprawl and Its Governance Challenges

Urban sprawl is a persistent and complex global phenomenon, presenting multifaceted governance challenges across both developed and developing contexts. Early theoretical perspectives by McGee (1991) and Robinson (1995) conceptualized sprawl in Southeast Asia as an outcome of rapid peri-urbanization, where rural and urban systems converge to form dynamic transition zones. These early models, particularly McGee's "desakota" framework, emphasized how spatial expansion without institutional coordination produces hybrid landscapes that strain governance systems. However, recent research suggests that the nature of sprawl has evolved, influenced by digital economies, speculative land markets, and changing patterns of mobility and housing demand (Bhatta, 2010; Angel et al., 2021).

In the South Asian context, contemporary studies indicate that urban sprawl now occurs within a more complex socio-political environment, where weak planning institutions and fragmented land governance continue to hinder sustainable urban growth (Yap, 2019; Hasan, 2022). In Sri Lanka, urban sprawl manifests as a combination of formal and informal expansion processes, often outpacing municipal control mechanisms. Wijayawardhana and Samarasekara (2022) identify unregulated land speculation and inadequate municipal enforcement as primary drivers, leading to fragmented land use, service disparities, and social displacement. Within the Kaduwela Municipal Council (KMC) area, these dynamics are intensified by proximity to Colombo, where

peri-urban development has accelerated due to improved transport networks and rising housing demand.

Governance responses to urban sprawl in Sri Lanka remain predominantly reactive. Gunaratne and Jayasinghe (2023) observe that overlapping jurisdictions between the Urban Development Authority (UDA) and local councils create institutional uncertainty, delaying development approvals and enforcement. This echoes Robinson's (2002) argument that institutional pluralism without coordination weakens spatial governance and fosters policy fragmentation. Political interference further complicates municipal planning, as short-term priorities override strategic urban management (Perera & Abeywickrama, 2021). Although the National Physical Planning Policy (2021–2040) promotes compact and sustainable urban development, its implementation depends heavily on strengthening local institutional capacity, enhancing inter-agency coordination, and integrating spatial data tools to inform proactive decision-making.

GIS in Urban Planning and Governance

Since the early 2000s, Geographic Information Systems (GIS) have transformed urban planning and governance, shifting decision-making from static, map-based approaches to dynamic spatial intelligence frameworks. Globally, GIS is now recognized as a core tool for managing urban complexity, enabling authorities to visualize land-use change, assess infrastructure capacity, and predict growth patterns (Batty et al., 2012; World Bank, 2021). In Southeast Asia, McGee's (1995) insights into spatial hybridity have been complemented by spatial analytics that allow real-time monitoring of peri-urban growth (Webster, 2011).

In Sri Lanka, GIS adoption has increased steadily in municipal planning, providing a scientific basis for evidence-based governance (Fernando et al., 2022). GIS allows integration of remote sensing data with demographic and cadastral records, supporting zoning, infrastructure planning, and environmental risk assessment. However, Samarasinghe and Silva (2021) note that adoption remains inconsistent across municipalities due to inadequate technical capacity, limited funding, and data management challenges. Jayasundara and Rajapakse (2023) further highlight that most local councils lack trained GIS personnel and face data interoperability issues, constraining their ability to apply spatial data in policy formulation.

The government's Smart Colombo initiative and the Urban Policy Dialogue (2022) have emphasized digital transformation and spatial data integration as key pillars of sustainable urban governance (Ministry of Urban Development and Housing, 2022). These policies mark a shift toward digital urbanism but require institutional commitment and capacity-building to achieve full implementation. In municipalities such as Kaduwela, the lack of GIS-driven spatial frameworks remains a key barrier to sustainable planning, despite growing recognition of its potential benefits.

GIS-Based Governance Solutions to Urban Sprawl

Recent empirical evidence demonstrates that GIS-based systems can significantly improve municipal governance by enhancing transparency, spatial accountability, and inter-agency coordination. In developing cities, GIS tools are increasingly used to detect unauthorized construction, optimize land use, and improve fiscal efficiency (UN-Habitat, 2020). In Sri Lanka, Jayasinghe et al. (2023) found that GIS-enabled monitoring systems reduce administrative delays and strengthen compliance with zoning regulations. The Urban Development Authority's (2022) pilot projects in Gampaha and Dehiwala–Mount Lavinia demonstrated a 30% reduction in permit processing times and improved spatial coordination among planning departments.

For Kaduwela, GIS-based property tax mapping has improved revenue collection and provided more accurate land-use data for planning purposes (Perera et al., 2022). This aligns with global best practices, where GIS-supported fiscal mapping is used to broaden municipal tax bases and improve resource allocation (World Bank, 2021). However, as Amarasinghe and Tennakoon (2020) note, fragmented data systems and lack of standardized spatial formats continue to limit interoperability across agencies. The Digital Local Governance Program (2023) addresses this gap by proposing a unified national GIS data standard to ensure consistency and data sharing between local governments and national authorities.

The international literature reinforces that GIS is not merely a technical instrument but a governance innovation that supports strategic decision-making. In Indonesia, Bangladesh, and Vietnam, GIS-based land information systems have contributed to curbing unplanned sprawl and promoting inclusive urban growth (World Bank, 2021). These experiences provide a relevant model for Sri Lankan municipalities to emulate as they transition toward data-driven urban management.

Governance Structures and Spatial Planning in the Kaduwela Municipal Council

Kaduwela's urban expansion exemplifies the governance dilemmas that accompany rapid peri-urbanization in South Asia. Silva and Gunawardena (2023) argue that the municipality's limited authority over land-use decisions—dominated by central agencies such as the UDA—undermines local responsiveness and accountability. This top-down planning structure mirrors earlier critiques by McGee (1991), who noted that centralized governance often marginalizes local participation in spatial planning. The result is a disconnect between ground-level urban realities and institutional planning objectives.

KMC's planning framework remains constrained by outdated documents and minimal GIS integration. Ratnayake and Perera (2021) report that over 60% of development permits issued in recent years lacked spatial verification, leading to irregular drainage networks and infrastructure inefficiencies. The 2023 Kaduwela Urban Profile highlights a severe shortage of GIS-trained personnel—only two out of thirty-eight technical staff possess formal GIS qualifications—limiting the municipality's analytical capacity. However, recent initiatives such as the 2023 Local Government Innovation Grant have introduced GIS training and pilot projects, including a GIS-based waste management system that has improved service efficiency and coverage (Urban Planning Forum Sri Lanka, 2024).

Regional collaboration remains essential. Jayasundara (2024) emphasizes that Kaduwela's spatial transformation is interdependent with neighboring municipalities such as Maharagama, Battaramulla, and Homagama. A coordinated regional approach—supported by interoperable GIS platforms—could enable integrated planning and mitigate cross-boundary sprawl. As part of the emerging Colombo Metropolitan Region, Kaduwela's transition toward proactive and data-driven planning is vital for achieving balanced, resilient, and sustainable urban growth.

Methodology

Research Design

Introduction

This study employs a GIS-based quantitative research methodology to evaluate the challenges of municipal governance in managing urban sprawl in the Kaduwela Municipal Council area of Sri Lanka. The research analyses spatial and temporal patterns of urban expansion from 2002 to 2025 using satellite imagery and geospatial datasets. Remote sensing techniques are applied to detect land use changes and assess the extent and intensity of urban sprawl. Landsat imagery is used as the primary data source, supported by municipal records and land use maps for accuracy and validation. Spatial overlay analysis is conducted to identify areas of significant land conversion, enabling precise detection of urban growth trends. This GIS-driven approach provides a systematic framework for monitoring urban expansion, pinpointing sprawl hotspots, and evaluating their implications for municipal governance. The methodology supports evidence-based urban planning by delivering accurate spatial insights essential for managing development and promoting sustainable land use practices

Study Area

The study focuses on the Kaduwela Municipal (KM) Council, the largest city by land area in Sri Lanka, spanning approximately 87.71 square kilometers within the Colombo District, Western Province. Kaduwela comprises key divisions such as Kaduwela, Battaramulla, and Athurugiriya, and is bounded by the Kelani River to the north and significant urban and peri-urban features on other sides. As of 2022, the population reached 281,282, reflecting rapid urban growth and diverse land use patterns, making it a critical area for assessing the impacts of urban sprawl and municipal governance effectiveness.

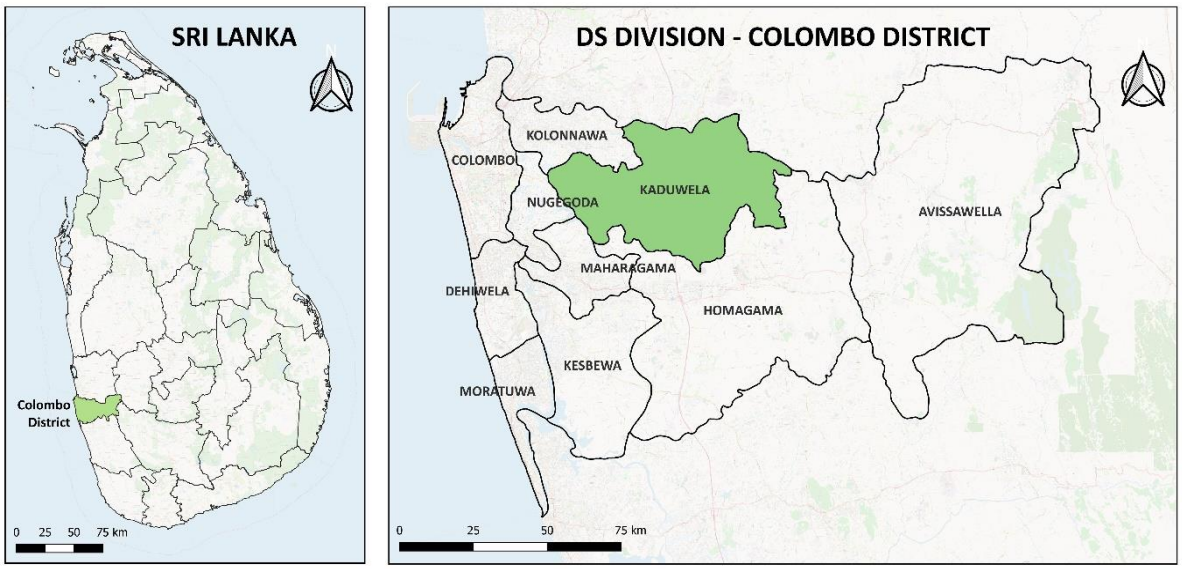


Fig. 1: Location of Kaduwela MC Area
Source: author

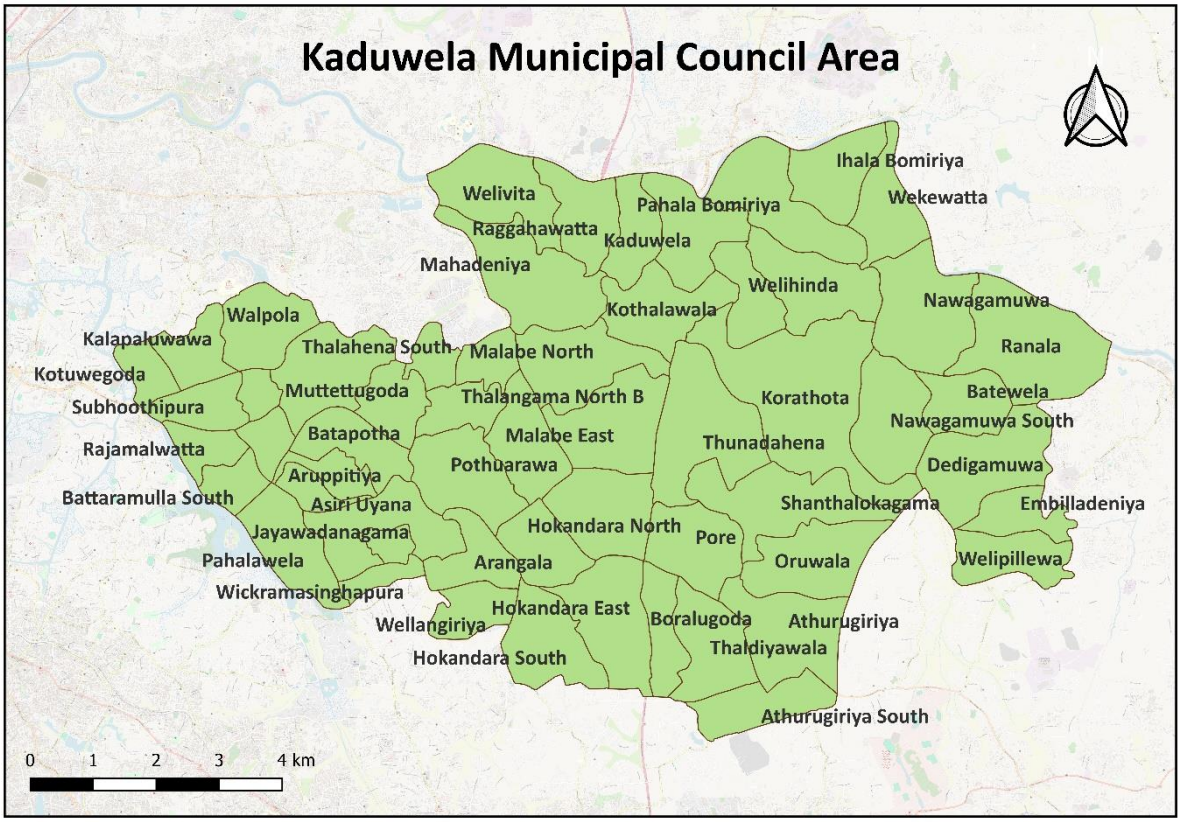


Fig. 2: Kaduwela MC Area
Source: author

Unit of Analysis

The Kaduwela Municipal Council (KMC) encompasses 57 Grama Niladhari (GN) Divisions, the smallest administrative units facilitating local governance and spatial analysis within the study area. Employing GN Divisions as the primary units of analysis allows for a detailed examination of urban sprawl patterns and associated governance challenges at a localized scale. This approach enhances the precision of spatial assessments and supports the development of context-specific policy interventions, thereby strengthening the capacity of the KMC to implement targeted and effective urban management strategies.

Data Collection

This study utilized a quantitative data collection approach to examine urban sprawl in the Kaduwela Municipal Council area. Satellite imagery and geospatial data were acquired from the Survey Department of Sri Lanka and the USGS Earth Explorer to support GIS and remote sensing analysis. Additionally, socio-economic and demographic statistics were obtained from the Department of Census and Statistics, Sri Lanka. These datasets facilitated a spatially grounded assessment of land use changes, enabling a detailed understanding of urban expansion and its implications for municipal governance.

Method of Analysis

This study adopts an integrated quantitative–spatial analytical framework designed to examine the governance challenges arising from urban sprawl within the Kaduwela Municipal Council (KMC) area. While Geographic Information Systems (GIS) and remote sensing are established tools in spatial research, this study advances their application by combining multi-temporal Landsat data (2002, 2012, and 2024) with demographic and socio-economic datasets to reveal the interplay between population dynamics, land-use transformation, and governance performance.

The analysis integrates supervised land-cover classification with statistical interpretation of demographic indicators to quantify spatial-temporal change and its implications for municipal management. By overlaying spatial datasets with administrative and infrastructure boundaries, the study identifies zones of high urban pressure and governance vulnerability. This multi-layered approach enhances the diagnostic value of GIS beyond descriptive mapping, providing evidence-based insights into spatial inequalities and planning inefficiencies.

Furthermore, the study's methodological innovation lies in contextualizing GIS-based results within governance assessment criteria, linking spatial outcomes directly to institutional capacity, regulatory enforcement, and service delivery performance. This alignment ensures that spatial findings are not treated in isolation but critically interpreted within the framework of municipal decision-making and sustainable urban development. The analytical design therefore moves beyond conventional spatial analysis to deliver a more policy-oriented, governance-integrated understanding of urban sprawl in Kaduwela MC.

Findings and Analysis

Introduction to the Analysis

To analyze spatial and demographic patterns within the Kaduwela MC area to evaluate the challenges of municipal governance in managing urban sprawl; It integrates statistical and geospatial data to identify the dynamics of population growth, land use transformation, and infrastructure distribution over the past two decades. Geographic Information System (GIS) tools were employed to visualize and assess the spatial relationships among demographic variables and land cover changes. The analysis draws on multiple data sources, including population census data from 2002, 2012, and 2023; household and employment statistics; and remote sensing imagery from the USGS Earth Explorer (Landsat 3, 4, 5, 7, 8, 9 and 10) for the years 2002, 2012, and 2024. These datasets enabled the classification of land into built-up areas, vegetation (dense and sparse), water bodies, and agricultural land, providing a comprehensive foundation for understanding the spatial implications of urban expansion in Kaduwela MC.

Demographic Trends and Urban Pressure

Population Growth Trends (2002, 2012, 2023)

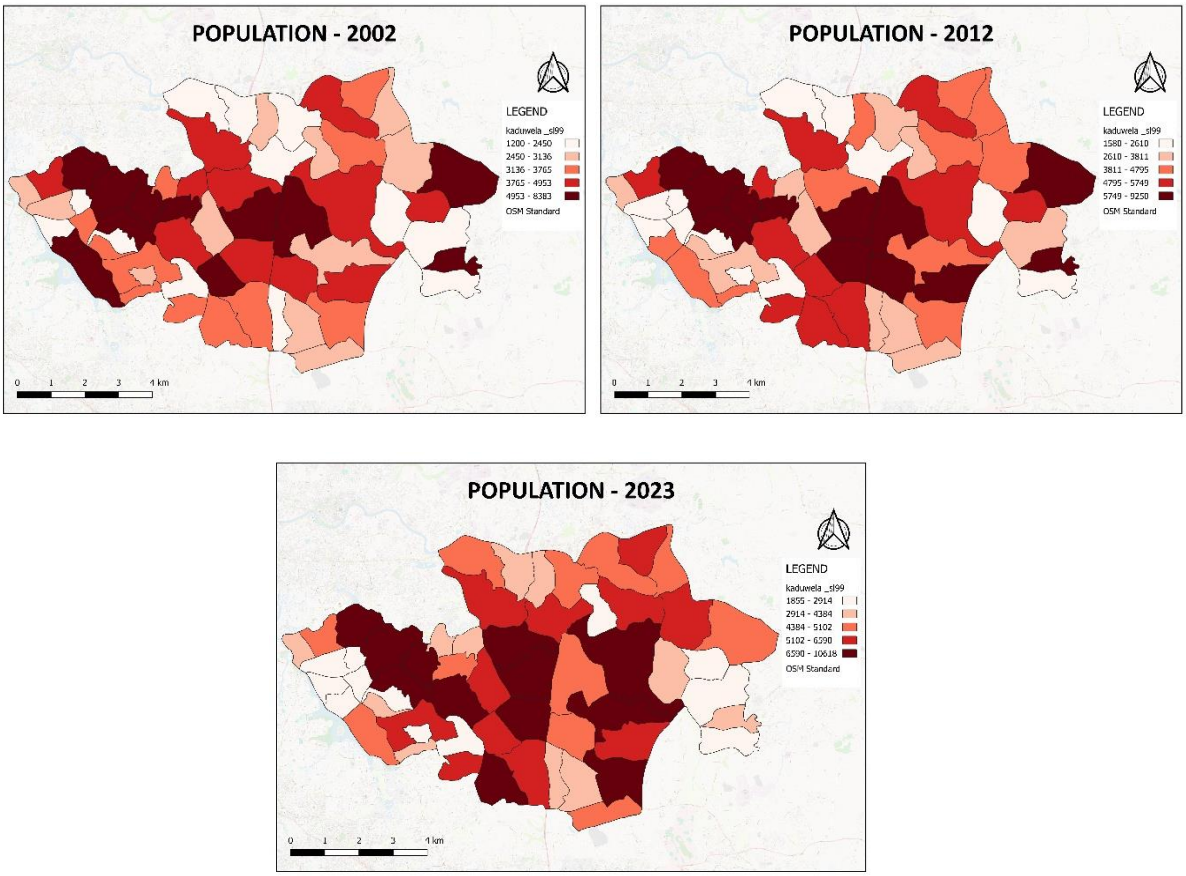


Fig. 3: Population 2002-2012-2023 - Kaduwela MC
Source: author

The Population Growth Trends: an increase in population across the Kaduwela MC area from 2002 to 2023, with a clear spatial expansion from central and western divisions to the peripheries. High

population concentrations are notably observed in areas adjacent to administrative and urban service centres such as Kaduwela, Malabe, and Athurugiriya. This growth reflects urban sprawl influenced by expanding residential zones beyond core urban boundaries. Administrative divisions that initially recorded moderate population levels have experienced significant densification, challenging traditional governance structures. As boundaries remain static while populations shift dynamically, municipal authorities face difficulties in equitable service delivery, spatial planning, and infrastructure allocation. These trends emphasize the urgent need for adaptive governance frameworks that align with evolving demographic patterns and spatial realities within Kaduwela MC's jurisdiction.

Population Density Distribution

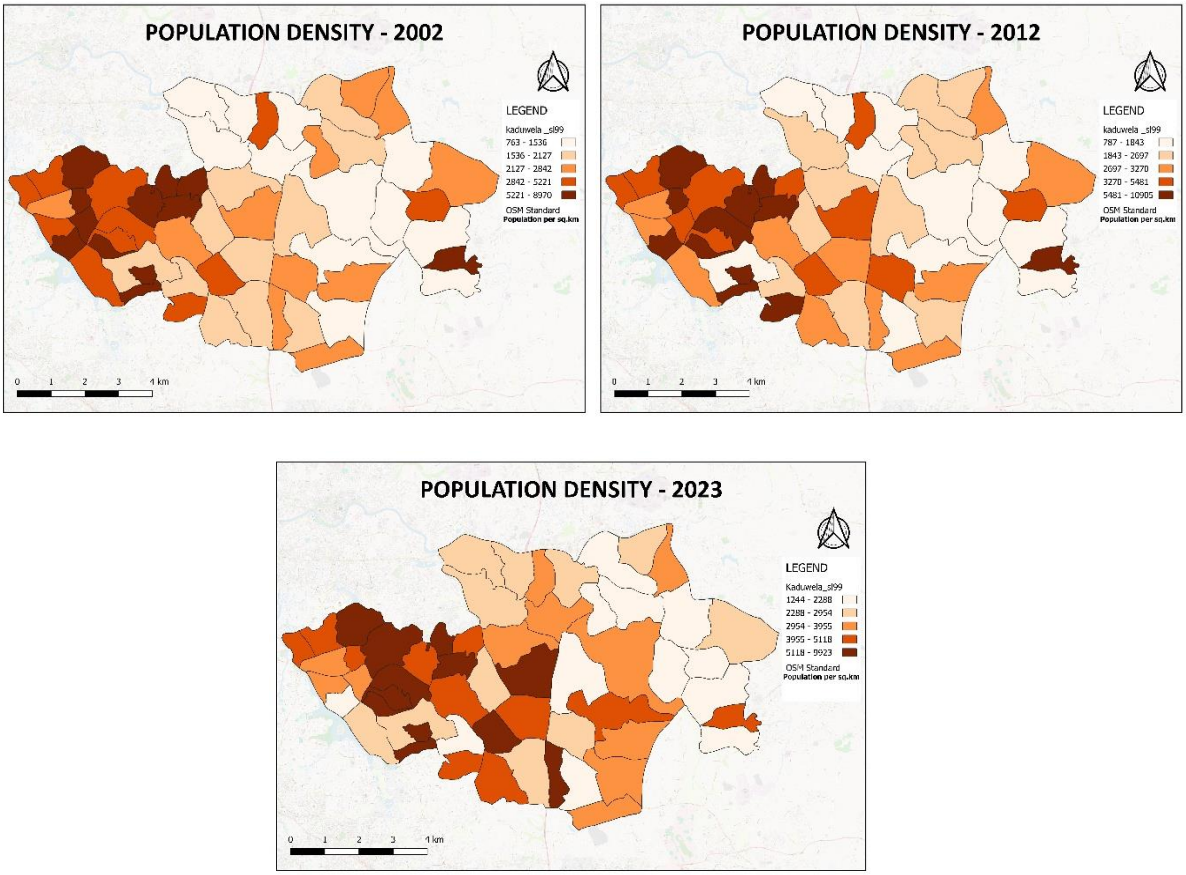


Fig. 4: Population Density 2002-2012-2023 - Kaduwela MC
Source: author

The spatial analysis of population density from 2002 to 2023 highlights a progressive intensification in specific areas within Kaduwela MC, especially in the southwestern and central divisions. These high-density zones reflect proximity to Colombo and major transport corridors, indicating a surge in land demand for residential and commercial purposes. In contrast, northeastern and peripheral divisions remain relatively low in density, suggesting uneven development and urban pressure. This imbalance creates a dual challenge: overburdened services in dense zones and underutilized infrastructure in sparse areas. For municipal governance, such

disparities complicate planning and equitable service provision. The patterns underscore the urgency for spatially responsive urban management strategies to address infrastructure deficits, regulate land use, and mitigate unplanned sprawl in high-density urbanizing sectors.

Population Growth Rate (2001–2023)

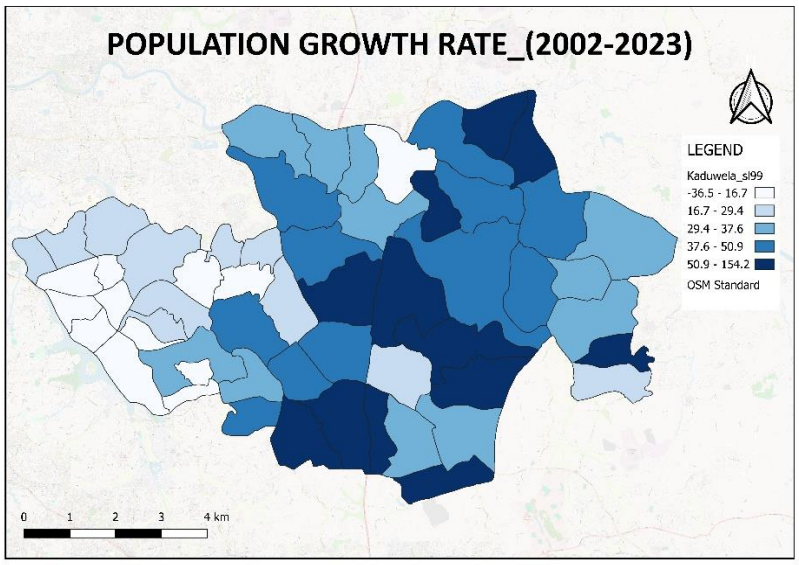


Fig. 5: Population Growth 2002-2023 - Kaduwela MC
Source: author

The population growth, shown as uneven growth across the Kaduwela MC area, with significantly accelerated growth concentrated in central and southeastern divisions. Areas such as Malabe, Kothalawala, and Athurugiriya exhibit growth rates exceeding 50.9%, reflecting their strategic location near Colombo and along major transportation routes like the Outer Circular Expressway. This correlation highlights how proximity to urban centres and improved infrastructure catalyse rapid demographic expansion. Conversely, divisions in the western periphery recorded stagnant or even negative growth, indicating a shift in residential preference towards well-connected, emerging suburbs. This demographic transformation poses governance challenges related to infrastructure demand, land management, and sustainable urban planning, necessitating targeted interventions by municipal authorities to mitigate the pressures of urban sprawl and ensure balanced spatial development.

Household Density (2023)

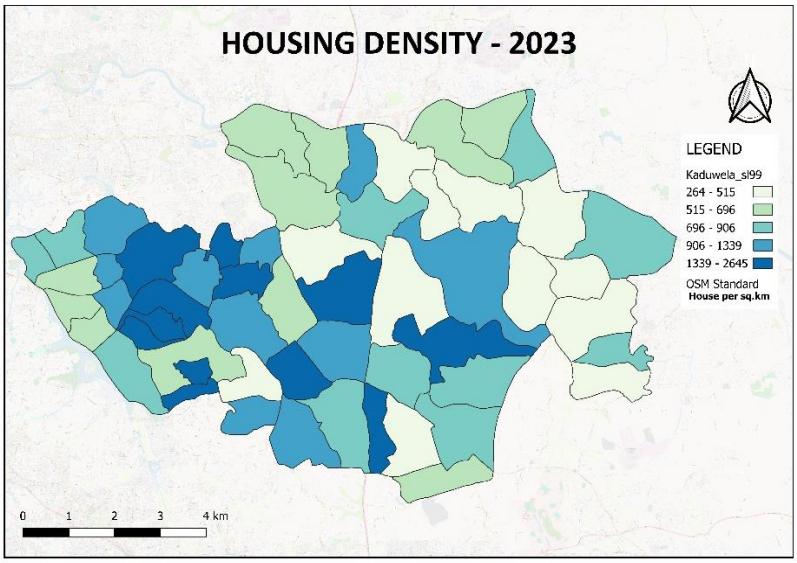
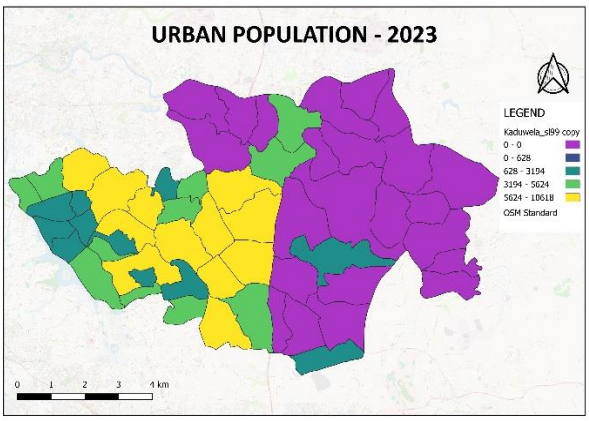


Fig. 6: Housing Density 2023 - Kaduwela MC
Source: author

The 2023 household density map reveals pronounced spatial disparities across Grama Niladhari (GN) Divisions within the Kaduwela MC. Higher concentrations of housing are observed in the western and southwestern zones, reflecting intensified residential development linked to improved accessibility and proximity to urban cores. In contrast, the northeastern and southeastern divisions remain relatively low in housing density, signaling ongoing peri-urban expansion. These patterns highlight emerging sprawl indicators, as housing growth extends toward peripheral areas without corresponding infrastructure upgrades. For municipal governance, this uneven housing distribution underscores the necessity of spatially guided planning to control informal expansion, ensure adequate public service delivery, and align residential growth with environmental sustainability and zoning regulations in managing urban sprawl within Kaduwela's administration.

Sector Population Classification (Urban / Semi-Urban – 2023)



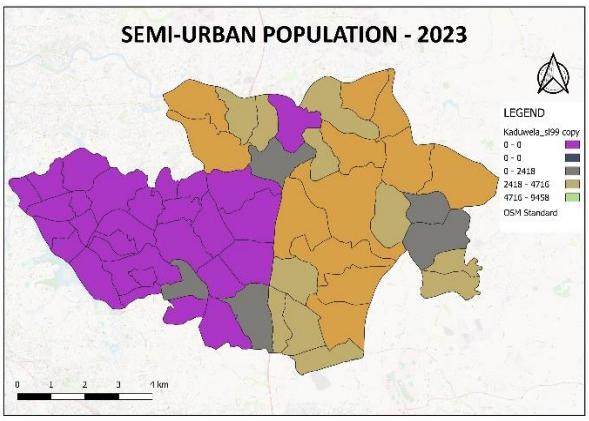


Fig. 7: Urban and Semi-Urban Population 2023 - Kaduwela MC
Source: author

The 2023 sector classification map of Kaduwela MC indicates a significant spatial expansion of urban zones, particularly in the eastern and central divisions. These areas exhibit high urban population concentrations, suggesting increased infrastructure, service accessibility, and residential clustering. In contrast, semi-urban populations dominate the northern and southeastern GN Divisions, highlighting transitional zones affected by spillover from core urban areas. This semi-urban encroachment reflects early indicators of unmanaged sprawl, as development pushes beyond traditional urban boundaries without adequate planning mechanisms. For municipal governance, these dual pressures demand strategic intervention to balance urban growth while preventing unregulated peri-urban development. Addressing this gradient is crucial to ensure coordinated infrastructure provision, sustainable land use, and the containment of sprawl within the Kaduwela MC governance.

Socioeconomic Indicators Related to Urban Sprawl

In-migration Rate (2023)

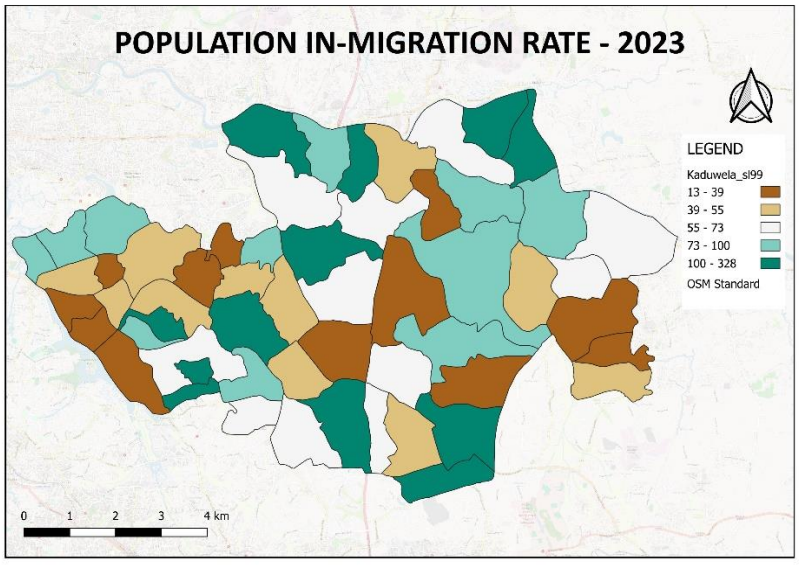


Fig. 8: In-Migration 2023 - Kaduwela MC
Source: author

The spatial distribution of in-migration rates in Kaduwela MC (2023) highlights key migration hotspots, particularly in the southern and western GN Divisions. These areas exhibit elevated inflow levels, suggesting the presence of strong urban pull factors such as employment opportunities, educational institutions, and improved transport connectivity. The heterogeneous migration patterns indicate localized attractiveness driven by service provision and infrastructure investments. However, this uneven influx imposes substantial pressure on municipal governance, particularly in managing land use, public services, and housing demands. Without coordinated spatial planning, such trends risk accelerating unregulated urban sprawl.

Employment Rate (2023)

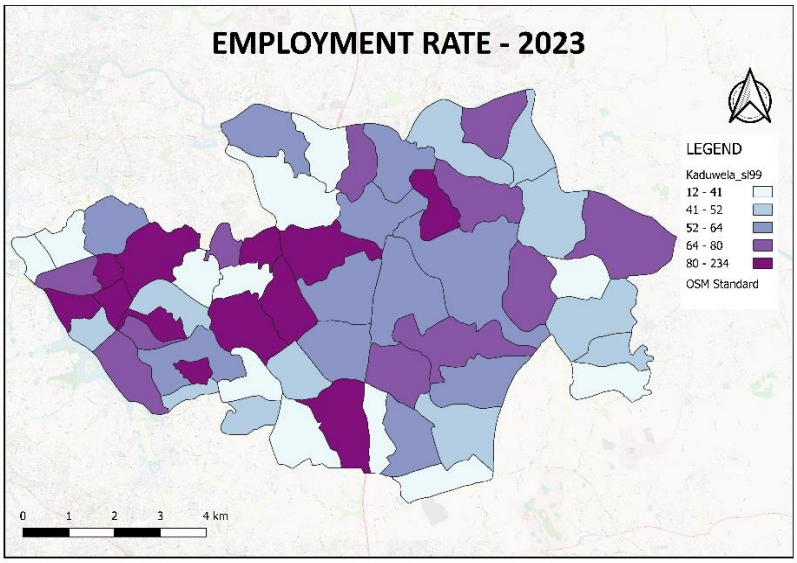


Fig. 09: Employment Rate 2023 - Kaduwela MC
Source: author

The spatial variation of employment rates across Kaduwela MC in 2023 reveals a significant correlation between employment hubs and urbanization patterns. Higher employment concentrations are observed in the central and western GN Divisions, reflecting the clustering of industrial zones, service sectors, and accessible transport corridors. This employment-driven urbanization contributes to localized densification and the expansion of built-up areas, acting as a catalyst for in-migration and commercial development. Conversely, peripheral regions with lower employment rates exhibit reduced urban intensity, highlighting spatial inequality in economic opportunities.

Infrastructure and Spatial Growth Patterns

Road Density (2023)

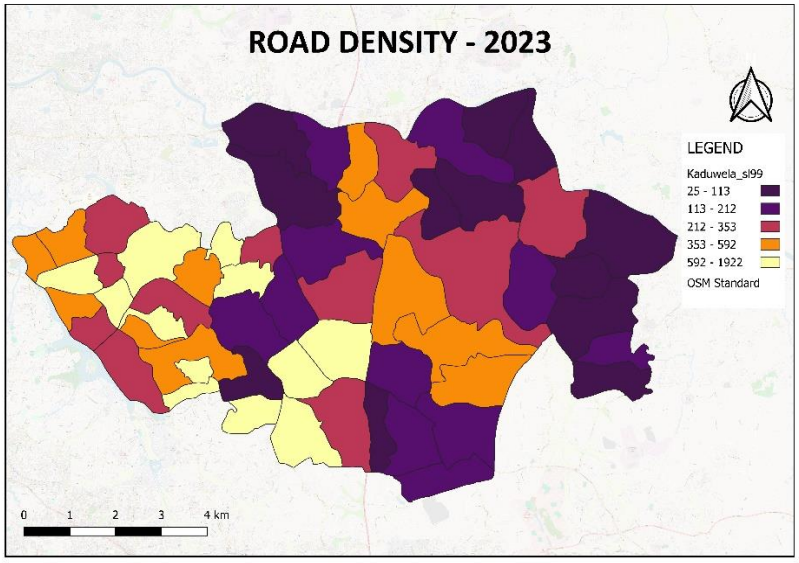


Fig. 10: Road Density 2023 - Kaduwela MC
Source: author

The 2023 road density distribution across Kaduwela MC reveals a significant correlation between transportation infrastructure and patterns of land use conversion. GN Divisions with higher road density, notably in central and eastern sectors, exhibit intensified urban development and land transformation, supporting greater residential and commercial expansion. While enhanced road networks improve urban accessibility and stimulate economic activity, they simultaneously accelerate urban sprawl and place pressure on existing infrastructure. Peripheral zones with lower road density remain less accessible, hindering equitable development. These disparities highlight a dual challenge for municipal governance: leveraging road expansion to promote balanced growth while mitigating congestion and uncontrolled land conversion.

Land Use and Land Cover Change Analysis (2002–2012–2024)

Methodology Recap

The Land Use and Land Cover (LULC) change analysis for 2002, 2012, and 2024 employed multi-temporal Landsat imagery (Landsat 4/5 TM, Landsat 7 ETM+ and Landsat 8 OLI/TIRS), selected for consistent spatial and spectral resolution. A supervised classification method was conducted using QGIS, categorizing land cover into Built-up, Dense Vegetation, Agriculture, and Water. Accuracy assessment was performed using ground-truth data and confusion matrices to validate classification reliability. This methodological framework enables precise detection of urban expansion and ecological transformation, providing a critical basis for understanding urban sprawl dynamics and informing sustainable municipal land management in the Kaduwela Municipal Council area.

Land Use Transformation (2002–2012-2024)

Built-up Area Expansion

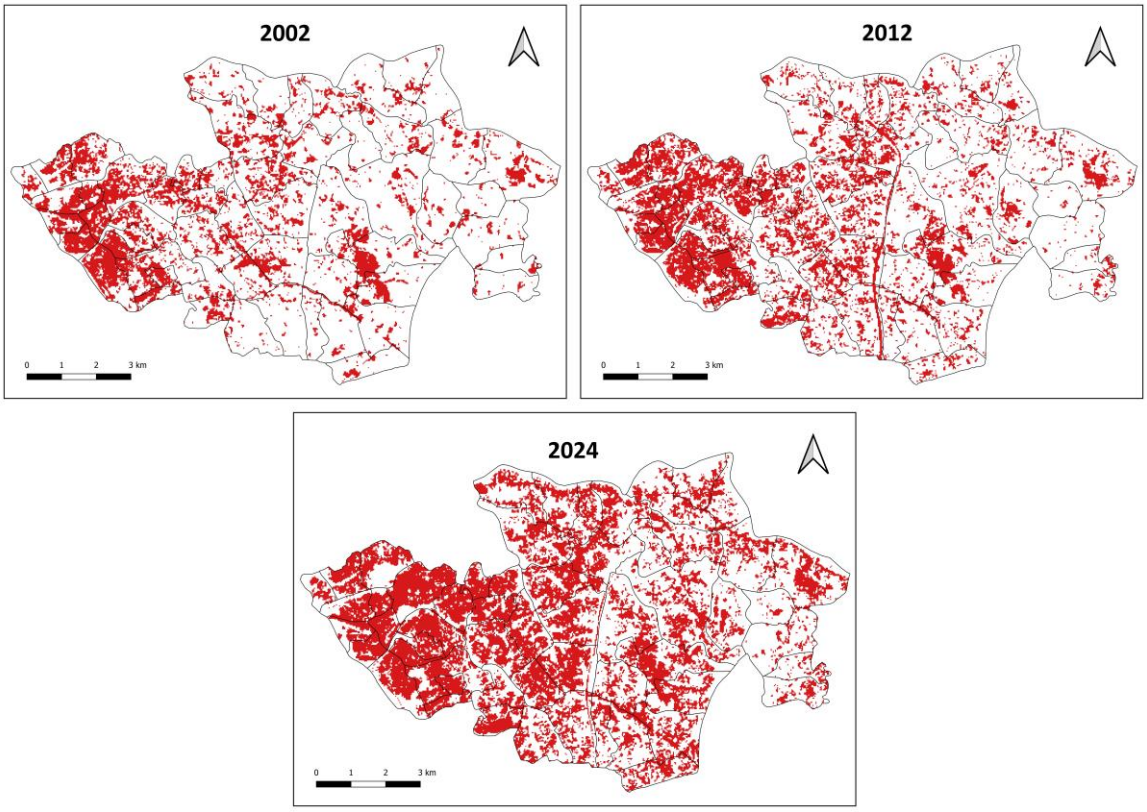


Fig. 11: Built-up Area 2002/2012/2024 - Kaduwela MC
Source: author

The built-up area within the Kaduwela Municipal Council (KMC) has experienced a significant spatial transformation between 2002 and 2024. As illustrated in the maps, the urban footprint increased from 19% in 2002 to 26% in 2012, and further expanded to 49% by 2024. This substantial growth reflects rapid urban sprawl, particularly in western and southern sectors, driven by infrastructure development and population influx. The widespread conversion of agricultural and green spaces into residential and commercial areas highlights increased pressure on land-use policies and housing demand. This trend presents significant governance challenges for KMC, necessitating the implementation of integrated land management strategies, zoning reforms, and sustainable urban planning to mitigate unregulated development and ensure equitable access to land and environmental preservation.

Vegetation Cover Change

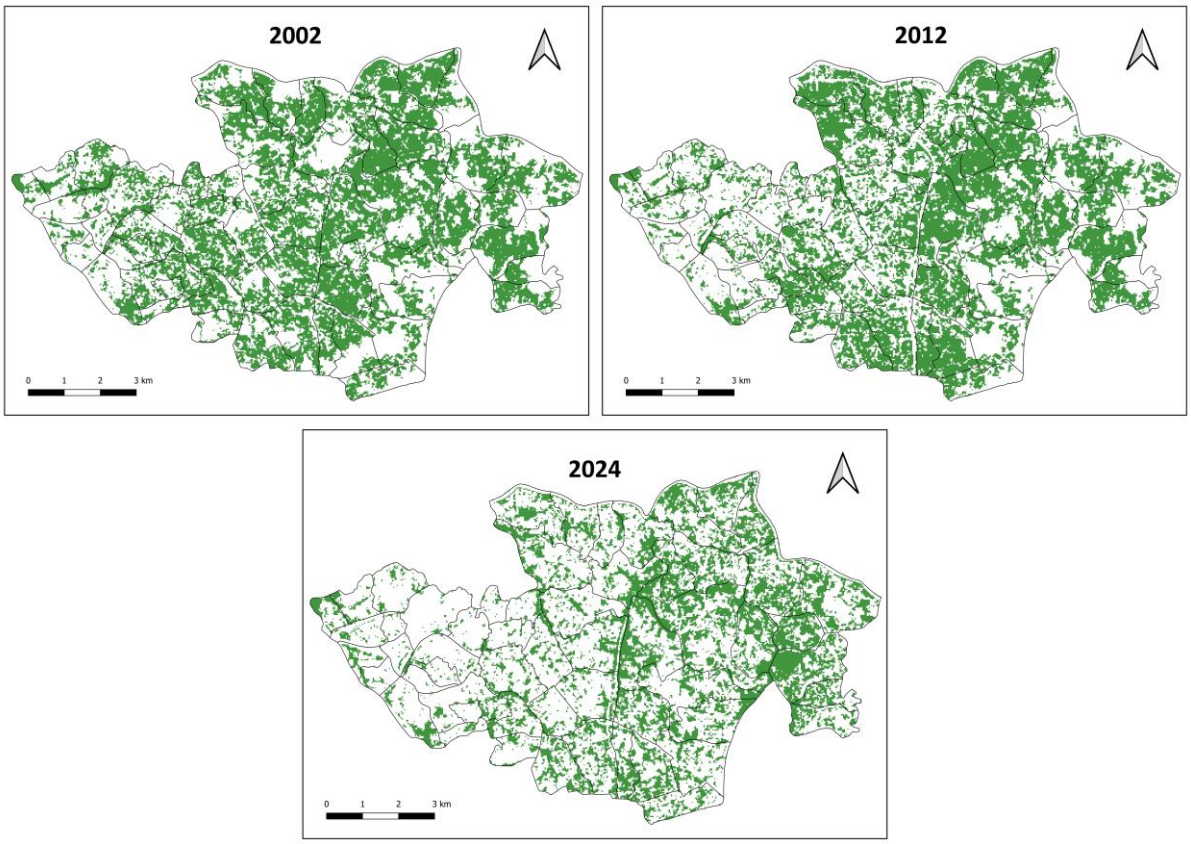


Fig. 12: Vegetation Cover 2002/2012/2024 - Kaduwela MC
Source: author

Vegetation cover in the Kaduwela Municipal Council (KMC) exhibited a fluctuating yet ultimately declining trend from 2002 to 2024. While the area covered by vegetation slightly increased from 51% in 2002 to 55% in 2012, it sharply declined to 37% by 2024. The spatial maps reveal a transformation from dense green cover to fragmented and sparse vegetation patches, particularly in central and western zones. This reduction is largely attributed to urban sprawl, informal settlements, and infrastructural encroachments. The observed forest loss and green space degradation pose serious ecological and planning challenges, undermining environmental sustainability. The fragmentation of green areas necessitates proactive governance interventions, such as green buffer zoning, urban forest restoration, and integration of green infrastructure into municipal planning frameworks.

Water Bodies

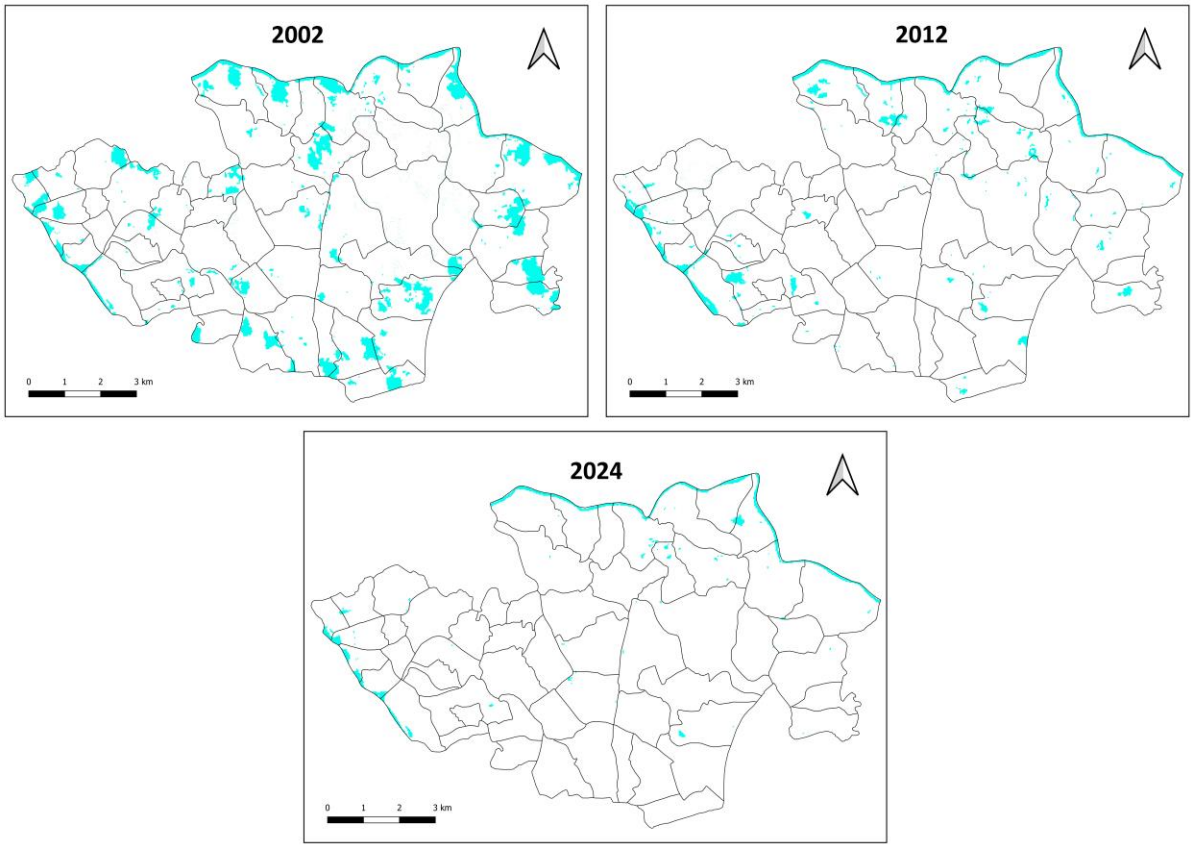


Fig. 13: Water Bodies 2002/2012/2024 - Kaduwela MC
Source: author

The spatial analysis of water bodies in the Kaduwela Municipal Council (KMC) indicates a marked decline over the study period, dropping from 9% in 2002 to 5% in 2012, and further to 3% by 2024. The maps reveal significant shrinkage and fragmentation of surface water resources, with numerous small and medium-sized water bodies disappearing, particularly in western and southern regions. This reduction is closely linked to unregulated urban expansion, land reclamation, and infrastructure development. The decline in aquatic ecosystems threatens long-term water security, biodiversity, and local climate regulation. These changes highlight the urgent need for integrated urban water management policies, preservation of natural drainage systems, and stricter zoning laws to safeguard remaining water resources amid rapid urban sprawl.

Agricultural Land Decline

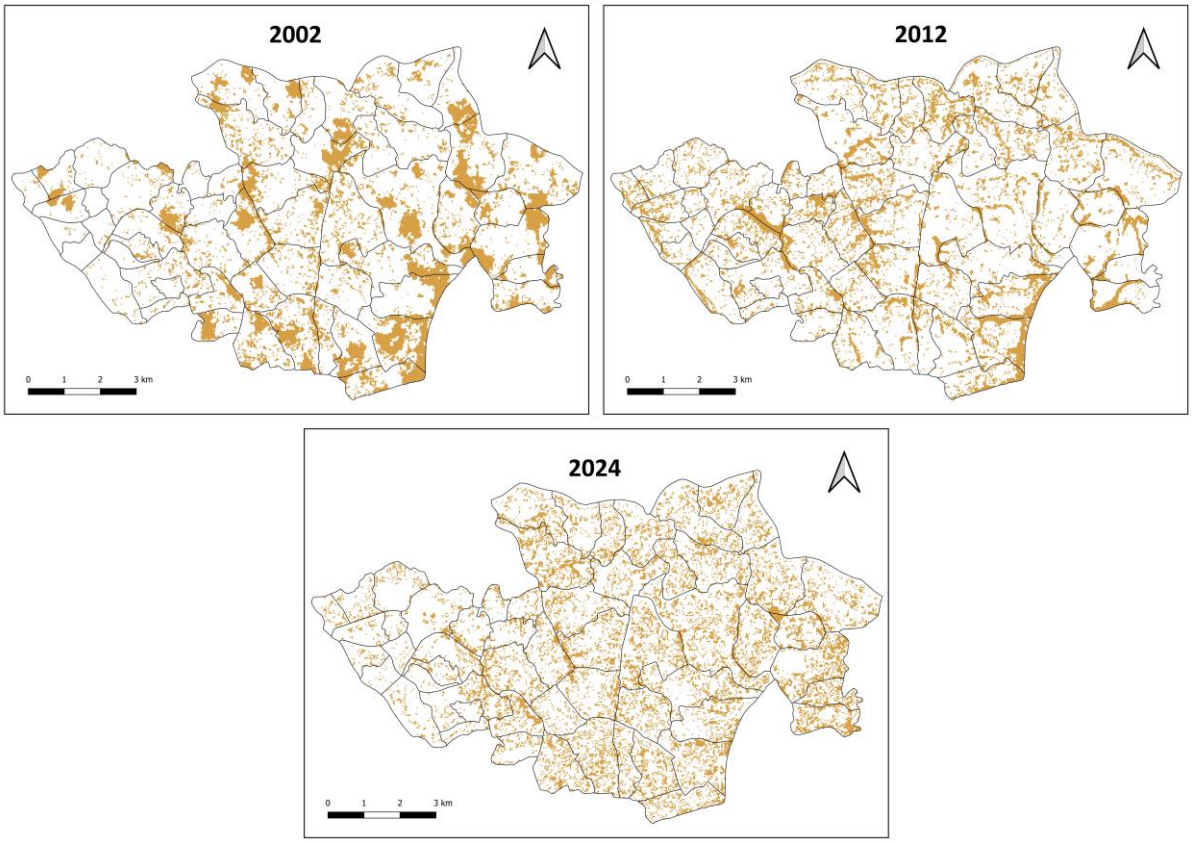


Fig. 14: Agriculture Land decline 2002/2012/2024 - Kaduwela MC
Source: author

The decline in agricultural land within the Kaduwela Municipal Council (KMC) area is a prominent indicator of ongoing urban sprawl. Agricultural land cover decreased from 18% in 2002 to 14% in 2012 and further declined to 11% by 2024. The spatial pattern highlights a progressive transformation of agricultural zones—especially in central and southern sectors—into residential, commercial, and industrial uses. This land conversion is driven by increased urban demand, infrastructure expansion, and changing land market dynamics. The urban–rural interface has become increasingly blurred, leading to the fragmentation of remaining agricultural parcels and disruption of local food systems. These trends pose significant governance challenges, underscoring the need for land-use regulation, peri-urban agricultural preservation strategies, and sustainable urban-rural development planning.

Summary Land Use Transformation (2002–2012-2024)

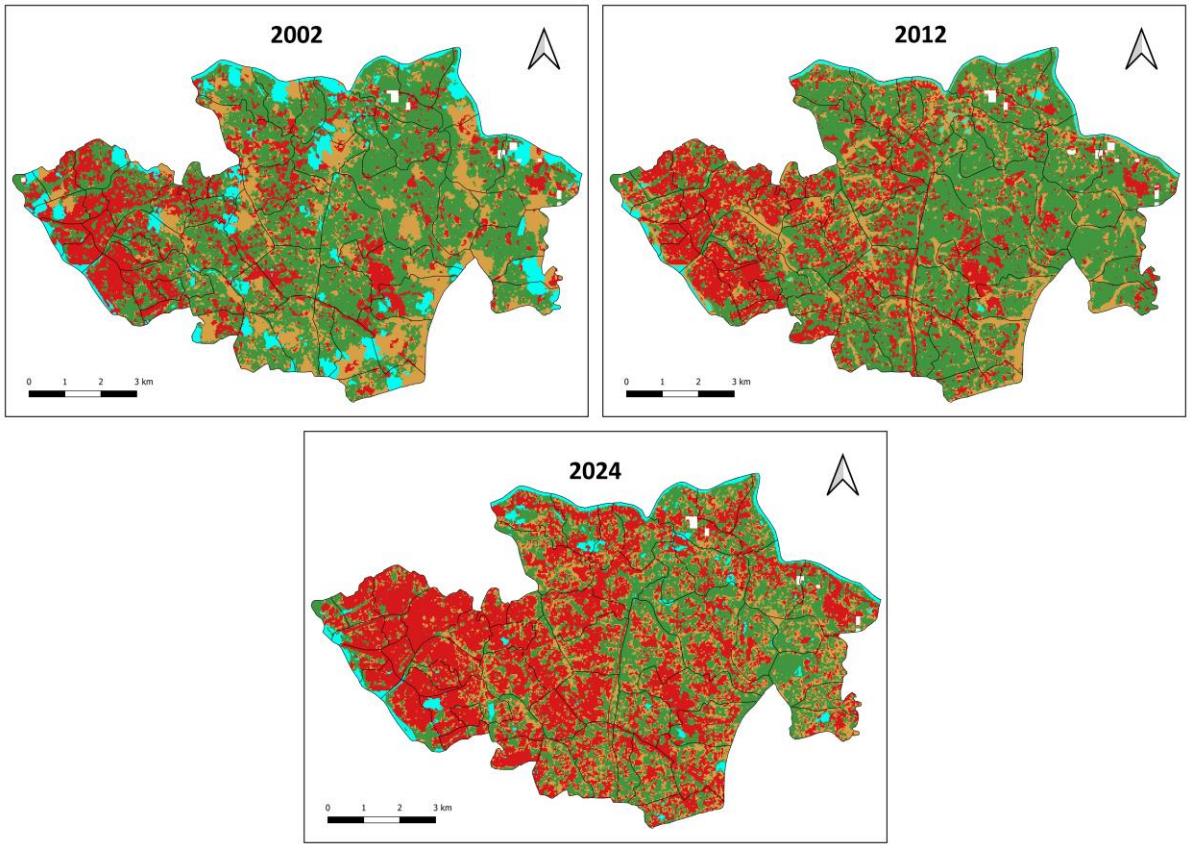


Fig. 15: Summary of the land use transformation 2002/2012/2024 - Kaduwela MC
Source: author

Spatial analysis reveals significant land use transformation in the Kaduwela Municipal Council (KMC) area between 2002 and 2024. Built-up areas expanded dramatically from 19% to 49%, primarily encroaching on agricultural (18% to 11%) and vegetative lands (51% to 37%). Composite land cover maps and encroachment patterns indicate pronounced urban sprawl in western and southern regions, driven by infrastructure development and population growth. Concurrently, water bodies declined from 9% to 3%, reflecting ecological degradation. These trends expose governance challenges in managing land conversion, environmental sustainability, and urban-rural transitions. The findings underscore the need for integrated land-use planning, green buffer zoning, and strengthened municipal policy to mitigate the impacts of unregulated development.

Synthesis of Key Spatial Trends and Governance Challenges

The spatial-temporal analysis of Kaduwela Municipal Council (KMC) from 2002 to 2024 reveals a strong correlation between population growth, in-migration, and built-up area expansion. High-growth divisions such as Malabe and Athurugiriya reflect over 50% demographic increase, coinciding with significant residential and commercial development. However, this urban expansion has outpaced infrastructure provision, resulting in a pronounced spatial mismatch. Densely populated and high in-migration zones face overburdened transport, sanitation, and public services, while peripheral divisions remain underutilized. These patterns illustrate the

complexity of managing urban sprawl, where land use conversion, from vegetation and agriculture to built-up areas, has accelerated environmental degradation and disrupted ecological balance. Governance challenges are compounded by static administrative boundaries, inadequate zoning enforcement, and a lack of integrated spatial planning, which hinder effective land regulation and service delivery. Collectively, the findings underscore urban sprawl as a multi-dimensional issue, encompassing demographic dynamics, socio-economic shifts, and environmental vulnerability. The emerging pressures on land, infrastructure, and natural resources demand a paradigm shift in municipal governance.

Recommendation

Based on the spatial-temporal analysis of demographic, socioeconomic, and land use dynamics in the Kaduwela Municipal Council (KMC), effective governance of urban sprawl necessitates an integrated, adaptive, and spatially responsive policy framework. Firstly, municipal authorities should adopt dynamic land-use planning mechanisms incorporating GIS-based monitoring to regularly assess urban expansion and ecological degradation. Secondly, zoning regulations must be revised and strictly enforced to prevent informal settlements and unchecked conversion of agricultural and vegetative lands. Establishing green buffer zones and peri-urban agriculture protection policies will support environmental sustainability and food security. Moreover, infrastructure development, particularly in transportation, sanitation, and public services should be equitably distributed to mitigate service overload in dense areas and stimulate development in underutilized regions. Given the static nature of administrative boundaries, a restructuring of governance zones aligned with evolving demographic realities is essential. Furthermore, the promotion of transit-oriented development and mixed-use planning around growth nodes like Malabe and Athurugiriya can ensure balanced urbanization. Finally, participatory planning approaches involving local stakeholders can enhance transparency, accountability, and contextual relevance of urban policies. These strategic interventions are crucial to mitigating the adverse impacts of unregulated sprawl while fostering sustainable, equitable, and resilient urban development within the KMC jurisdiction.

Recommendations for Future Studies

Future research on municipal governance and urban sprawl in the Kaduwela Municipal Council (KMC) area should adopt a more comprehensive and interdisciplinary approach that integrates spatial, socio-economic, and environmental dimensions. Building on the present study's GIS-based findings, subsequent research should incorporate longitudinal datasets and real-time spatial monitoring systems to capture ongoing urban transformations with greater temporal precision. This would enable researchers to identify emerging hotspots of land-use change and assess their policy implications more effectively.

Future investigations should also examine the socio-economic consequences of urban sprawl, including housing affordability, transportation accessibility, and livelihood transformations in peri-urban areas. Integrating household surveys and participatory mapping techniques can provide valuable insights into how residents experience and adapt to spatial and infrastructural inequalities. Furthermore, future studies should explore the intersection between urban sprawl and climate resilience by analyzing flood risk exposure, green space connectivity, and ecosystem degradation within KMC's expanding built environment.

Methodologically, combining GIS with spatial econometrics and remote sensing–based machine learning models could enhance the accuracy of spatial predictions and policy simulations.

Comparative analyses between Kaduwela and other rapidly urbanizing municipalities in Sri Lanka would also strengthen understanding of regional urbanization trends and governance responses. Finally, future research should prioritize collaboration between academic institutions, local authorities, and planning agencies to translate spatial evidence into actionable urban policies. Such partnerships can foster adaptive, data-driven governance that balances urban development with ecological sustainability in Sri Lanka's evolving urban landscape.

Conclusion

This study assessed the challenges of municipal governance in managing urban sprawl within the Kaduwela Municipal Council (KMC) area using GIS-based spatial and demographic analysis over the period 2002–2024. The findings clearly demonstrate that rapid and uneven urban expansion has fundamentally reshaped Kaduwela's spatial, environmental, and socio-economic landscape. Built-up areas have expanded dramatically from 19% in 2002 to nearly half of the total land area by 2024, largely at the expense of vegetation, agricultural land, and water bodies. This transformation has been driven by population growth exceeding 50% in key divisions such as Malabe and Athurugiriya, accompanied by high in-migration and employment concentration near transport corridors and service hubs.

The spatial patterns reveal a pronounced imbalance in urban development, densification in central and western divisions contrasts with stagnation in peripheral areas. These disparities have produced service delivery gaps, infrastructure congestion, and governance strain, particularly in rapidly urbanizing sectors. The static administrative boundaries and limited institutional coordination have further exacerbated the mismatch between population distribution, infrastructure provision, and land management capacity. As a result, KMC faces mounting difficulty in ensuring equitable access to public services, maintaining ecological balance, and regulating informal expansion.

The degradation of vegetation (from 55% to 37%), loss of agricultural land (from 18% to 11%), and decline of water bodies (from 9% to 3%) signal significant environmental consequences of unregulated growth. These ecological losses highlight the urgent need for spatially integrated urban management, where land-use decisions incorporate environmental thresholds and sustainability criteria. The GIS-based spatial evidence underscores that without strategic land-use regulation, sprawl will continue to outpace municipal capacity, intensifying pressure on infrastructure and environmental systems.

This research contributes to municipal governance studies in rapidly urbanizing South Asian contexts by demonstrating the value of GIS as a diagnostic and planning tool. The analytical approach used here provides a replicable model for local authorities to monitor spatial transformations and assess policy effectiveness. For Kaduwela MC, the results emphasize the necessity of adopting adaptive governance measures such as dynamic zoning, green buffer restoration, and cross-sectoral planning coordination to mitigate spatial inequalities and environmental degradation.

Future research should expand this spatial analysis by integrating socio-economic and climate resilience dimensions, particularly housing affordability, mobility patterns, and vulnerability mapping, to better inform adaptive urban governance. Incorporating real-time spatial data, participatory planning tools, and scenario-based simulations would further enhance the capacity of municipal institutions to anticipate and manage urban growth sustainably.

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