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Original Article

Assessing Spatio-Temporal Change of Urban Expansion on Vegetation Cover -A Case of Kigali City

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Rapid urban growth has become one of the key global drivers of land-use change, significantly impacting the natural environment, particularly vegetation cover. This research focused on quantifying and analyzing the spatial and temporal change of urban growth and its consequent effects on the city's vegetation cover, assessing the loss and degradation of vegetation cover, and identifying the factors contributing to changes in land use and vegetation. The research problem was the limitation in the way of understanding the spatiotemporal changes in vegetation cover due to urban growth in Kigali city. Therefore, this research was focused on the main objective which was to assess the spatiotemporal change of urban expansion on vegetation cover, a case of Kigali city. Specific objectives were: assessing the driving factors of urban expansion in Kigali city, to analyze the variation change in vegetation cover in Kigali city over twenty-four years and to examine the relationship between urban expansion and vegetation loss in Kigali city. The methods used were library research by reading different books, papers and journals, which helped the researchers to do literature review. Household surveys helped to understand how urban expansion impacts local residents' access to green spaces, environmental changes, and their general perceptions of vegetation loss. Satellite imagery from multiple time frames, processed using advanced GIS and remote sensing techniques, were used to analyze land use/land cover changes, with a focus on vegetation loss and the spatial-temporal dynamics of urban growth. Key informants' interviews provided in-depth, qualitative insights that complemented quantitative data from satellite imagery and GIS analysis. The results provided detailed maps of urban sprawl and vegetation cover changes in Kigali, with a focus on highlighting areas most vulnerable to degradation. Different main drivers of urban change such as population growth, economic development and rural-urban migration have been discussed. To sum up, the study found a significant decrease in vegetation cover over the past 24 years, a percentage of 90% caused by vegetation loss such as urban expansion, deforestation and poor urban planning, while a smaller percentage of 10% noted some efforts to increase vegetation through reforestation and green infrastructure projects land use and zoning regulation and the relationship between urban expansion and vegetation cover has shown that if urban growth is done in a sustainable way vegetation cover can be protected.

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INTRODUCTION

World's cities accommodate population growth by increasing the density of their current footprints and expanding into rural areas. In recent decades, urban expansion has accounted for the majority of population growth making an impact on vegetation cover. Urban expansion is one of the most significant drivers of environmental change globally (UN-Habitat, 2013). With more than half of the world's population now living in urban areas, urbanization continues to accelerate, particularly in developing countries (Uwera, E. (2020). This global trend is contributing to the conversion of natural landscapes into built environments, leading to a reduction in vegetation cover. Urban areas, though engines of economic growth, often experience challenges in maintaining a balance between development and environmental conservation in Rwanda (Nzabonimana, 2017). As cities expand, vegetation cover, which plays a crucial role in regulating climate, supporting biodiversity, and providing ecosystem services, is rapidly replaced by impervious surfaces such as roads, buildings, and other infrastructure (REMA, 2013). The impact of urbanization on vegetation cover has been extensively studied worldwide. In many cities, the replacement of vegetation with built-up areas leads to a host of environmental problems, including increased temperatures (urban heat island effect), reduced air quality, higher flood

risks, and the loss of carbon sequestration capacity (Ntakirutimana, 2019).

In Sub-Saharan Africa, rapid urbanization is a defining characteristic of the region's development trajectory (Goodfellow, 2013). According to the United Nations, Africa is expected to urbanize faster than any other region in the world, with urban populations in many countries projected to be more than double by 2050 (Angel, 2011). This rapid urban growth presents unique challenges, including pressures on vegetation and natural resources, especially in urban centres with limited land area such as Kigali, Rwanda.

The region faces an ongoing struggle to balance urban development with environmental sustainability. Cities are expanding at a rate that outpaces the capacity of local governments to manage the environmental impacts (Manuh, 2019). In particular, the conversion of vegetated land to urban areas has been linked to the loss of biodiversity, increased vulnerability to climate change, and reduced resilience to environmental shocks such as droughts and floods. In many African cities, vegetation loss is compounded by inadequate waste management, deforestation, and limited access to green infrastructure (Angel, 2011). In this regional context, assessing how urban expansion is impacting vegetation cover in cities like Kigali is crucial. By understanding these trends, regional governments and planners

can develop better policies and strategies to manage urban growth in ways that protect natural ecosystems while accommodating the needs of growing populations (Nshuti, 2019). Over the past few decades, Kigali has experienced rapid population growth, increasing from around 1 million people in 2010 to over 1.5 million people by 2024, with projections indicating that the population will continue to grow in the coming decades (Kayitesi, 2019). This population growth, combined with an influx of investment and infrastructure development, has contributed to the expansion of the urban landscape, often at the expense of natural areas and vegetation. Rwanda (Teller, 2021), and specifically Kigali, is located in a region with a high degree of biodiversity and ecological richness, yet this natural heritage is increasingly under pressure due to urban sprawl in Rwanda (Burns, 2021).

The current study, therefore, aims to assess the spatiotemporal change of urban expansion on vegetation cover, a case of Kigali city. Specific objectives include:

- Assessing the driving factors of urban expansion in Kigali city.
- To identify the variation change in vegetation cover in Kigali city over twenty-four years.
- To examine the relationship between urban expansion and vegetation loss in Kigali city.

MATERIALS AND METHODS

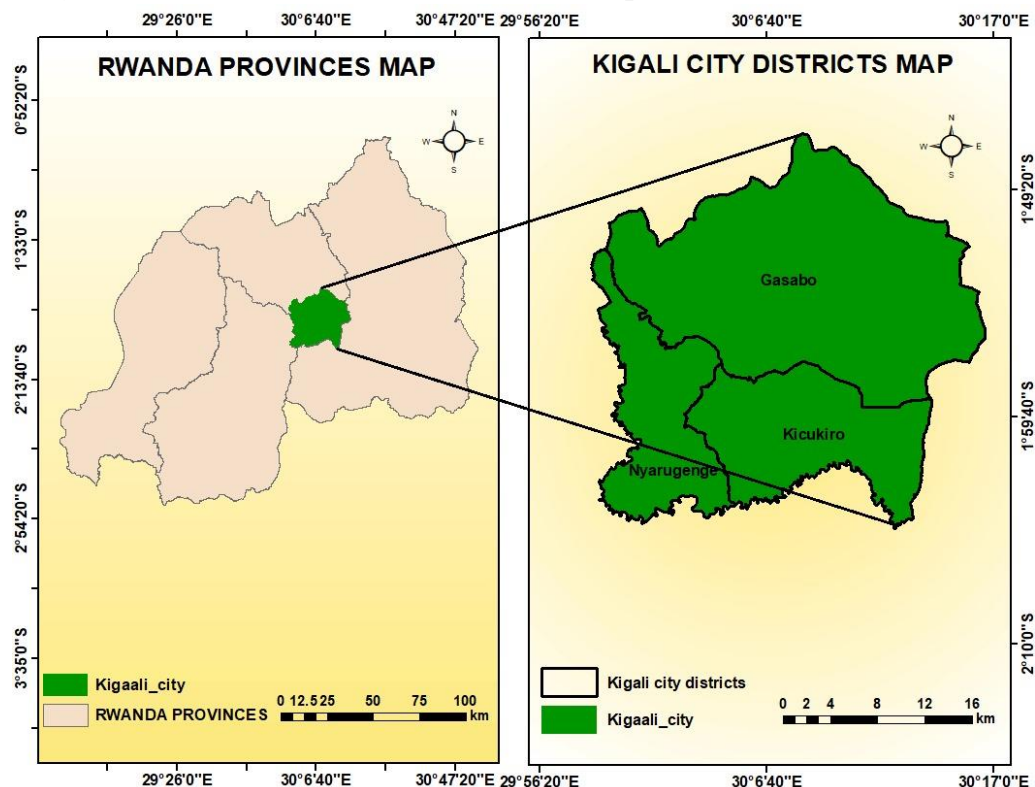
Description of the Study Area

Kigali City, the capital of Rwanda, will serve as the study area. With an estimated population of

over 1.6 million and it located on latitude - 1.940278 and longitude 29.73888. Kigali has experienced rapid urbanization in recent years. The city covers approximately 730 km² and is characterized by hilly terrain, green spaces, and a mix of urban and peri-urban landscapes. Key areas of focus include districts such as Gasabo, Kicukiro, and Nyarugenge, which showcase varying levels of urban development and vegetation cover and are composed of several administrative units: 35 sectors, subdivided into 161 cells and 1,061 villages. The elevation of the lowest part is roughly 1400 m, and the highest hills are at 1845 m above the mean sea level. Kigali's urban land uses include, mainly, residential, commercial, social, and public infrastructure (MINECOFIN, 2013). Agriculture occupies the largest proportion of the city's land area (60.5 %). The wetlands occupy 12.5 % of the total city's land area, and half of the wetlands' area is used for various land uses including, mostly, agriculture.

Hills and Mountains: Kigali is situated between prominent elevations, notably Mount Kigali and Mount Jali. Mount Kigali, located directly west of the city centre in Nyarugenge District, reaches an elevation of 1,853 meters. Mount Jali, to the north, stands taller at 2,078 meters. These elevations provide expansive views of the city and contribute to its hilly terrain (REMA, 2018).

Valleys and Slopes: The city's landscape comprises a series of valleys and ridges connected by steep slopes. This varied topography results in diverse microclimates and influences urban planning.

Figure 1: Study Area of Rwanda Provinces and District Maps

Source: Primary data, 2025

Sampling Design

Population of the Study

The study population included all areas within Kigali City affected by urban expansion, as well as relevant stakeholders such as urban planners, environmentalists, and local communities. Vegetation cover across urban, peri-urban, and rural-urban interfaces will also be examined.

Sample Size

A stratified sampling approach has been used to select representative areas for detailed analysis. The study focused on high, medium, and low urbanization zones within Kigali. The sample size for satellite image analysis has encompassed the entire city, while field validation focuses on 30 stratified sample sites.

Sampling Technique

Remote Sensing Sampling: Multispectral satellite images (e.g., Landsat and Sentinel) have been obtained for selected years to analyze temporal changes. **Field Sampling:** Stratified random

sampling has been used to select ground truth sites for vegetation and land-use validation. **Key Informant Interviews:** Purposive sampling has been employed to select 15-20 stakeholders for qualitative interviews, selected based on their expertise and relevance to urban planning and environmental issues.

Data Collection Procedures

Data were collected in the following phases:

Satellite Imagery Acquisition: High-resolution images from sources such as Landsat and Sentinel have been downloaded for analysis of urban expansion and vegetation cover changes over time. **Selection of Satellite Imagery through temporal resolution:** acquire satellite images from multiple time points within the 2000–2024 period to capture changes over specific intervals, such as annually or decennially. For instance, studies have utilized imagery from 2000, 2008, 2016 and 2024 to analyse urbanization patterns in Kigali City. **High-resolution images (e.g., 2m from WorldView-2)** are suitable for detailed urban

analysis, while medium-resolution images (e.g., 30m from Landsat) are effective for broader vegetation assessments.

Field Surveys: Ground Truthing, the study used field survey data to validate remote sensing classifications, enhancing the accuracy of land cover maps. This process ensured that satellite-derived data accurately represented on-the-ground conditions. Sampling Strategy has been used to develop a stratified random sampling approach to select representative sites across Kigali City. This method ensured that various land cover types, including urban areas, vegetation zones, and transitional regions, are adequately represented.

Stakeholder Engagement: Semi-structured interviews and focus group discussions with urban planners and local communities provided qualitative insights. Engaging stakeholders provided valuable insights into local knowledge, perceptions, and experiences regarding urban expansion and vegetation changes. Those stakeholders were government agencies and community groups with engagement methods such as Workshops and focus groups: The study used organized participatory workshops and focus group discussions to facilitate open dialogue among stakeholders, allowing for the exchange of knowledge and experiences and interviews: conduct in-depth interviews with key informants, such as urban planners, environmental experts, and community leaders, to gain detailed insights into specific aspects of urbanization and its impacts.

Questionnaires: Structured questionnaires will capture quantitative data related to the topic. Structured questionnaires have been used to make presentations across different demographics, neighbourhoods, and professional groups. Questionnaires serve as a vital data collection tool to gather quantitative and qualitative information from various stakeholders, including residents, urban planners, environmental experts, and policymakers. These questionnaires are designed to capture perceptions, experiences, and insights regarding urban expansion and its impact on

vegetation cover over the period from 2000 to 2024.

Key Informant Interviews: Interviews have been conducted with government officials, urban planners and environmental experts in discussion about urbanization plans and growth trajectories. As Kigali is experiencing rapid urban expansion, interviewers emphasized the importance of managing this growth in a sustainable way to ensure the city remains livable and also discussed how they are addressing the loss of vegetation due to urban expansion through regulations, conservation projects, and the integration of green infrastructure into urban development. This will provide policy-related insights to analyze the impact of urban expansion on vegetation cover in Kigali city.

Field Observations: Through Site Visits for Data Collection, field observations involved direct visits to various locations within Kigali City. These visits allowed researchers to observe vegetation cover, changes in land use, and urban expansion firsthand. The data collected in the field, such as photos, plant species identification, and descriptions of land use, have been compared with remote sensing or satellite imagery for more precise spatiotemporal analysis. This method also helped validate satellite data and refine its interpretation (Elvidge, 2012).

Data Processing

Data have been processed in the following steps:

Preprocessing: Satellite images have undergone radiometric correction, geometric correction, and cloud masking to improve accuracy.

Land-Use and Land-Cover Classification: Supervised classification techniques have been applied using the software ArcGIS. Vegetation indices like Normalized Difference Vegetation have been calculated. NDVI provides a quantitative measure of vegetation health and density, enabling the detection of changes in vegetation cover over time. This is particularly useful for identifying areas where urban expansion has led to vegetation loss. NDVI values

range from -1 to 1, where higher values indicate denser and healthier vegetation and lower values suggest sparse or absent vegetation (Nduwayezu *et al.*, 2021).

Temporal Analysis: Temporal analysis begins with collecting data from different time periods to observe how urbanization and vegetation cover have changed over time. Common sources of data include: Satellite imagery (e.g., Landsat, Sentinel, or Google Earth images), which can provide multi-temporal images at regular intervals (Getu *et al.*, 2021).

Satellite Imagery: Landsat, Sentinel in the interval period of twenty-five years from 2000 to 2024 years.

Calculate Normalized Difference Build-up Index will be calculated for monitoring urban growth. NDBI enables the identification and quantification of built-up areas over time, facilitating the analysis of urban expansion patterns in Kigali City. By comparing NDBI values across different time periods, researchers can assess the extent and rate of urbanization and evaluate vegetation loss that have taken place in Kigali city. Values of NDBI range from -1 to 1, where higher values indicate built-up areas and lower values suggest non-built-up areas.

GIS Analysis: GIS tools provide essential spatial analysis capabilities, enabling the examination of both the temporal and spatial aspects of the relationship between urban growth and vegetation loss. The integration of GIS with satellite data, field observations, and other geospatial datasets allows for a more comprehensive understanding of urbanization dynamics and environmental changes over time through creating maps showing vegetation changes and urban growth across Kigali's Districts over twenty- four years.

Tabulation summarizing quantitative data in tables: **Tabulation and summarizing quantitative data in tables** play an essential role in organizing, analyzing, and presenting the results of the **spatiotemporal changes in urban expansion and vegetation cover** in Kigali City. During the data processing phase, this approach

helps translate complex geospatial and temporal data into **clear, understandable, and actionable insights**.

RESULTS AND DISCUSSION

The study was guided by three main research objectives: (1) to identify the drivers of urban expansion, (2) to analyze the changes in vegetation cover over the past 24 years, and (3) to examine the relationship between urban expansion and vegetation loss. The chapter is structured to first present the results of the data collected through questionnaires and key informant interviews, followed by a discussion that integrates these findings with the existing literature and theoretical framework.

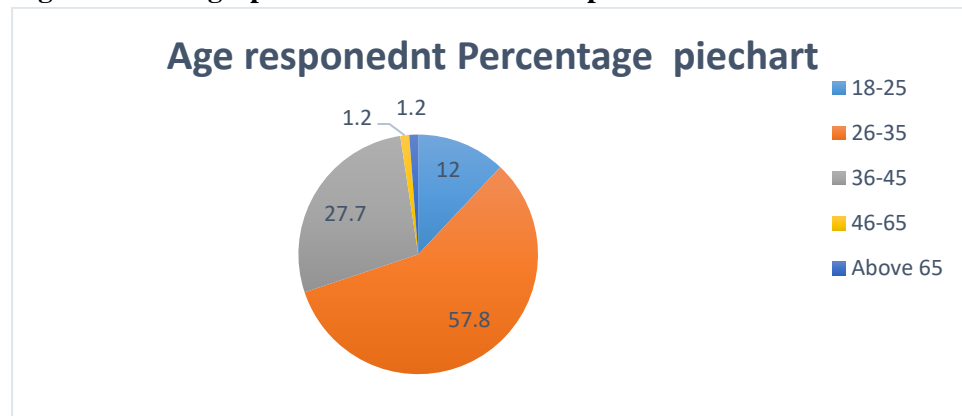
The data collection process involved a mixed-methods approach, combining quantitative data from structured questionnaires. The questionnaires were administered to a diverse group of respondents, including residents, urban planners, environmental experts, and government officials, to capture a wide range of perspectives on urban expansion and vegetation loss. Key informant interviews were conducted with professionals from government institutions and environmental organizations to gain deeper insights into the policies and practices influencing urban development in Kigali. The results are organized thematically, aligning with the research objectives. The first section presents the demographic characteristics of the respondents, the causes of vegetation loss, and the impact of urban expansion on environmental resilience. The chapter also discusses the effectiveness of current urban planning policies and provides recommendations for sustainable urban development.

Demographic Characteristics of Respondents

The respondents included a diverse group of residents, urban planners, environmental experts, and government officials. The majority of respondents were aged between 26-35 years (57.8%), with a significant number having resided in Kigali City for more than 10 years. This indicates that the respondents have a deep

understanding of the city's urbanization trends and environmental changes.

Figure 2: Demographic Characteristics of Respondents



Source: Primary data, 2025

Presentation of Findings

When presenting results for a study assessing the **spatiotemporal changes in urban expansion** and their impact on **vegetation cover in Kigali City**, research focused on a clear and structured approach for getting effective information in research.

Drivers of Urban Expansion

The rapid urban expansion in Kigali City is driven by a combination of socio-economic, demographic, and policy-related factors. The primary drivers identified by respondents include population growth, economic development, rural-urban migration, and government policies. Each of these drivers is discussed in detail below, supported by evidence from the questionnaire responses and relevant literature.

Population Growth (78%)

Population growth emerged as the most significant driver of urban expansion in Kigali City, with 78% of respondents identifying it as a key factor. The city's population has grown rapidly over the past two decades, increasing from approximately 1 million in 2010 to over 1.5 million in 2024, with projections indicating continued growth in the coming years. This population surge has created a high demand for housing, infrastructure, and services, leading to

the physical expansion of the city into surrounding rural areas.

The findings align with global trends, where population growth is a primary driver of urban expansion, particularly in developing countries (UN-Habitat, 2013). In Sub-Saharan Africa, rapid population growth has been a defining characteristic of urbanization, with cities expanding to accommodate the increasing number of residents (World Bank, 2017).

Economic Development (54%)

Economic development was identified by 54% of respondents as a major driver of urban expansion. Kigali's status as Rwanda's economic and administrative hub has attracted significant investment in infrastructure, commercial activities, and services. The availability of job opportunities in sectors such as manufacturing, services, and technology has drawn people to the city, further accelerating urban sprawl.

Economic development is a well-documented driver of urbanization, as cities often serve as centres of economic activity and employment (Zhang, 2022). In Kigali, the government's focus on transforming the city into a regional economic hub has further fuelled urban expansion (Kigali Master Plan 2050).

Rural-Urban Migration (66%)

Rural-urban migration was cited by 66% of respondents as a significant factor contributing to urban expansion. The influx of people from rural areas to Kigali has been driven by the search for better economic opportunities, improved living standards, and access to services such as education and healthcare. This migration has increased the demand for housing and infrastructure, leading to the conversion of vegetated land into built-up areas.

Rural-urban migration is a common phenomenon in rapidly urbanizing regions, particularly in Sub-Saharan Africa, where rural areas often lack economic opportunities and basic services (UN-Habitat, 2013). In Kigali, the migration trend has been exacerbated by the city's economic growth and its role as the country's administrative centre (REMA, 2015).

Land Market Dynamics (20%)

Land market dynamics were cited by 20% of respondents and it play a crucial role in driving urban expansion. The way land is bought, sold, and developed in response to economic, social,

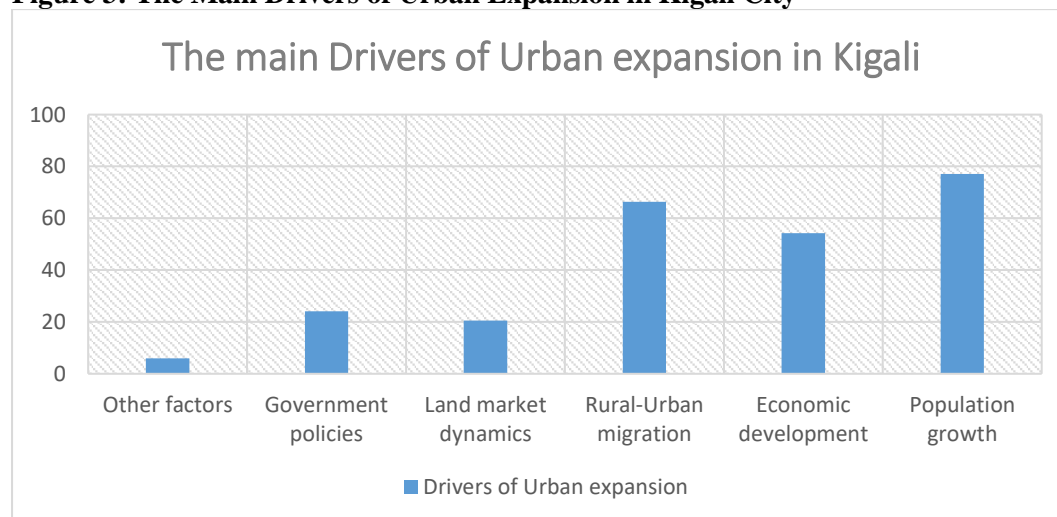
and policy influences affects how cities grow and change over time.

Government Policies (24%)

Government policies promoting urbanization and infrastructure development were identified by 24% of respondents as a driver of urban expansion. Rwanda's national development strategies, such as the Vision 2050 and the Green Growth and Climate Resilience Strategy, emphasize urbanization as a pathway to economic growth. These policies have encouraged investment in infrastructure, housing, and commercial developments, contributing to the physical expansion of Kigali.

Government policies play a critical role in shaping urban development, particularly in countries like Rwanda, where the state has a strong influence on economic and spatial planning (Emmanuel, 2007). The Kigali Master Plan 2050, for example, outlines a vision for the city's growth, including the development of new residential and commercial zones, which has implications for vegetation cover (Kigali City Council, 2020).

Figure 3: The Main Drivers of Urban Expansion in Kigali City



Source: Primary data, 2025

The findings above highlight the complex interplay of demographic, economic, and policy-related factors driving urban expansion in Kigali City. Population growth and rural-urban migration are closely linked, as the influx of

people from rural areas increases the demand for housing and infrastructure. Economic development further accelerates this process by creating job opportunities and attracting investment. Government policies, while aimed at

promoting sustainable development, have also contributed to urban sprawl by prioritizing infrastructure and housing projects.

These drivers are consistent with trends observed in other rapidly urbanizing cities in Sub-Saharan Africa, where population growth, economic development, and rural-urban migration are key factors shaping urban expansion (World Bank, 2017). However, the role of government policies in driving urbanization is particularly pronounced in Kigali, reflecting Rwanda's centralized

planning approach and its focus on transforming the city into a regional economic hub (Angel *et al.*, 2016).

Changes in Vegetation Cover

Urbanization typically involves construction, excavation, and other activities that disturb the soil. This leads to compaction, which reduces the soil's ability to retain water and nutrients necessary for plant growth. Changes in soil structure can thus hinder the establishment or survival of vegetation.

Table 1: Observed Changes in Vegetation Cover in Kigali City

Change	Percentage of Respondents
Decrease in Vegetation	90%
Increase in Vegetation	10%

Source: Primary data, 2025

Explanation: This table visually represents the overwhelming majority of respondents who observed a decrease in vegetation cover, with only a small percentage noting an increase.

The rapid urban expansion in Kigali City has had a significant impact on vegetation cover. The majority of respondents (90%) reported a decrease in vegetation cover over the past 24 years, while a smaller percentage (10%) noted some efforts to increase vegetation through reforestation and green infrastructure projects. This section explores the observed changes in vegetation cover, the causes of these changes, and their implications for the city's environment and resilience.

Decrease in Vegetation Cover (90%)

The overwhelming majority of respondents observed a decline in vegetation cover in Kigali City over the past 24 years. This loss of vegetation is primarily attributed to urban expansion, deforestation for construction, and poor urban planning. Respondents highlighted that the conversion of vegetated land into built-up areas has been a major factor in the reduction of green spaces.

The findings align with global trends, where urbanization often leads to the replacement of natural landscapes with impervious surfaces such

as roads, buildings, and other infrastructure (UN-Habitat, 2013). In Kigali, the loss of vegetation has been particularly pronounced due to the city's rapid growth and the lack of adequate environmental safeguards (REMA, 2015).

Increase in Vegetation Cover (10%)

While the majority of respondents reported a decrease in vegetation cover, a small percentage (10%) noted some efforts to increase vegetation through reforestation and green infrastructure projects. These efforts include tree planting initiatives, the creation of urban parks, and the rehabilitation of wetlands. However, these initiatives have been limited in scope and have not fully compensated for the overall loss of vegetation.

Rwanda's Green Growth and Climate Resilience Strategy emphasizes the importance of reforestation and green infrastructure in mitigating the environmental impacts of urbanization (REMA, 2015). However, the effectiveness of these initiatives has been limited by the rapid pace of urban expansion and the lack of enforcement of environmental regulations (Kigali Master Plan 2050).

Discussion of Changes in Vegetation Cover

The observed decrease in vegetation cover has significant implications for Kigali's environment and resilience. Vegetation plays a crucial role in regulating the local climate, maintaining water cycles, and preventing soil erosion, particularly in a city with steep terrain like Kigali. The loss of vegetation has also contributed to the urban heat island effect, where urban areas experience higher temperatures than their rural surroundings due to the lack of natural surfaces like vegetation and water.

The limited efforts to increase vegetation through reforestation and green infrastructure projects are a positive step, but they are not sufficient to offset the overall loss of green spaces. To address this issue, there is a need for more comprehensive urban planning that integrates green spaces into the city's development. This includes the creation of urban parks, tree-lined streets, and green roofs, as well as the protection of existing natural areas such as wetlands and forests.

Relation between Urban Expansion and Vegetation Cover

Urban expansion and vegetation cover are closely related, with urban growth often directly impacting the extent and quality of vegetation in the surrounding areas. The relationship is complex and involves multiple factors such as land-use changes, infrastructure development, resource consumption, and ecological disruption.

Conversion of vegetation to built-up areas: urban expansion typically involves the conversion of natural landscapes (such as forests, grasslands, and wetlands) into built-up areas like residential neighbourhoods, roads, and commercial zones (Herold *et al.*, 2003). This conversion directly reduces the area covered by natural vegetation (Kigali Master Plan 2050). Agricultural Land Conversion: Often, cities grow outward into agricultural land, replacing croplands with urban infrastructure. Although this does not always

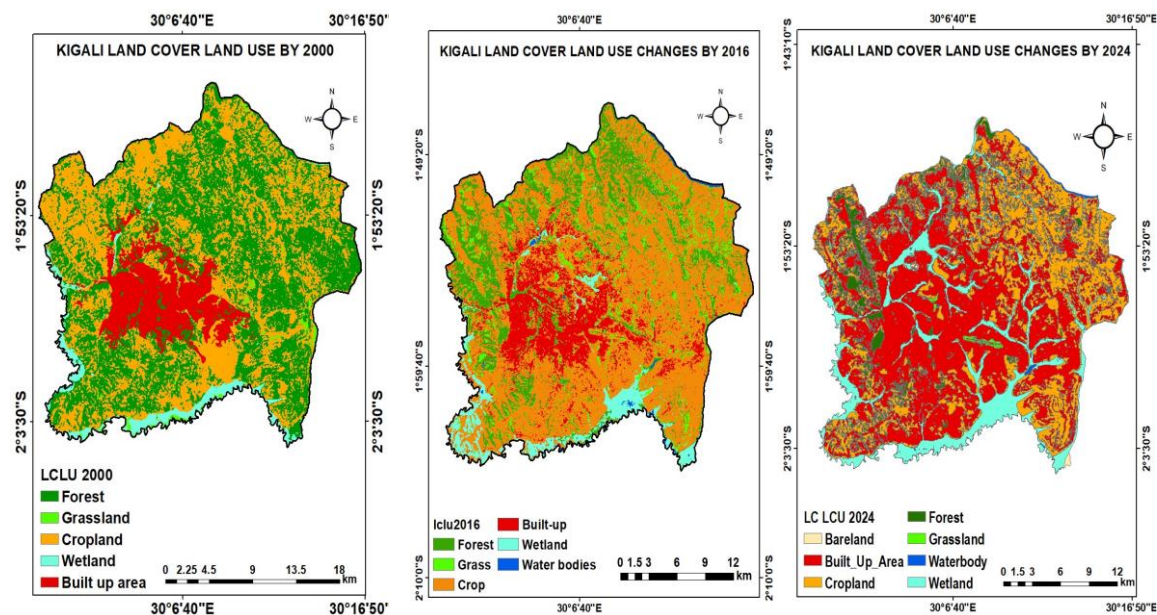
result in the direct destruction of native vegetation, it does shift the land use and can affect local ecosystems (Mahadevia *et al.*, 2018).

Habitat Fragmentation: As cities expand, they fragment large, continuous ecosystems into smaller, isolated patches of vegetation (Matthew. 2015). These fragmented patches are often too small or too isolated to sustain the biodiversity that once thrived in larger, continuous habitats. Smaller patches are also more vulnerable to disturbances like fire, storms, or human activity (Zhang, 2022). Native Vegetation Loss: Urban expansion often leads to the replacement of native vegetation with non-native or ornamental species in parks and gardens, further reducing the native plant species that would have naturally grown in the area. Non-native plants can sometimes outcompete native species, reducing overall biodiversity (REMA, 2015).

Pollution and Habitat Loss: Urbanization introduces pollution in many forms—air pollution, water runoff, noise, and light all of which negatively impact vegetation. Pollutants like nitrogen compounds can change soil composition, making it more difficult for native plants to survive (Kamanzi, 2018).

Stormwater Runoff and Reduced Water Availability: Urban development increases the number of impervious surfaces such as roads and buildings (Angel *et al.*, 2005). This reduces the amount of water that can naturally infiltrate the ground, altering the water availability for vegetation. Increased stormwater runoff can also lead to flooding and erosion, further degrading natural vegetation (World Bank, 2017). Soil Degradation: Urban expansion often involves the excavation and compaction of soils, which can affect their structure and nutrient content. This makes it more difficult for plants to take root and grow, leading to a reduction in vegetation cover (REMA, 2015).

Figure 4: Kigali Land Cover and Land Use Change between 2000-2024



Source: Primary data, 2025

Temporal Analysis of Vegetation Cover

Based on the above different maps which show how vegetation has been changed due to urban expansion, to further illustrate the changes in

vegetation cover over time, below is a table showing the decline in vegetation cover from 2000 to 2024. This table is based on satellite imagery data.

Table 2: Temporal Changes in Vegetation Cover in Kigali City (2000-2024)

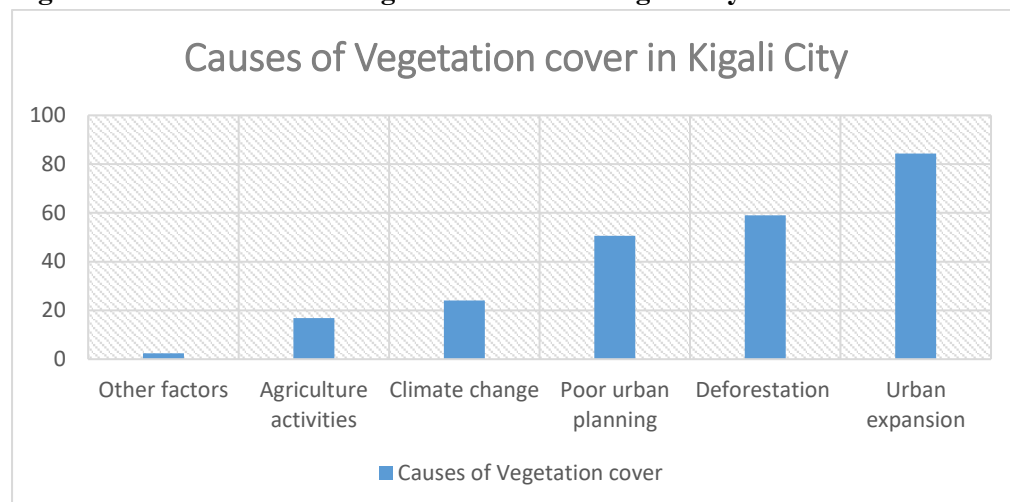
Year	Vegetation Cover (%)
2000	70%
2012	25%
2024	15%

Source: Primary data, 2025

Causes of Vegetation Loss

The loss of vegetation in Kigali City is driven by several interrelated factors like urban expansion, deforestation for construction, and poor urban planning being the most

frequently cited causes (Mutoni and Ntwali, 2024). These factors have led to the conversion of vegetated land into built-up areas, resulting in a significant reduction in green spaces. Below is a detailed analysis of each cause, supported by respondent insights and literature.

Figure 5: Cause of Loss of Vegetation Cover in Kigali City

Source: *Primary data, 2025*

Explanation: This chart visually represents the relative importance of each cause, with urban expansion being the most frequently cited factor.

Urban Expansion (85%)

Urban expansion was identified by 85% of respondents as the primary cause of vegetation loss in Kigali. As the city grows, it encroaches on surrounding rural areas, leading to the conversion of forests, wetlands, and agricultural land into residential, commercial, and industrial zones. This physical growth of the city has resulted in the loss of critical ecosystems that provide essential services such as climate regulation, water filtration, and biodiversity support.

Urban expansion is a global phenomenon, particularly in rapidly urbanizing cities in developing countries (Seto, 2012). The conversion of natural landscapes into built environments is a major driver of vegetation loss, leading to environmental degradation and reduced ecosystem services (UN-Habitat, 2013). In Kigali, the rapid pace of urban growth has outpaced the capacity of local governments to manage its environmental impacts (REMA, 2015).

Deforestation for Construction (59%)

Deforestation for construction was cited by 59% of respondents as a significant cause of vegetation loss. Trees are often cleared to make way for new buildings, roads, and infrastructure projects. This

deforestation not only reduces vegetation cover but also contributes to soil erosion, loss of biodiversity, and increased carbon emissions.

Deforestation for construction is a common issue in rapidly urbanizing cities, particularly in Sub-Saharan Africa, where urban expansion often occurs without adequate environmental safeguards (World Bank, 2017). In Kigali, the lack of strict enforcement of environmental regulations has exacerbated this problem (Kigali Master Plan 2050).

Poor Urban Planning (50%)

Poor urban planning was identified by 50% of respondents as a contributing factor to vegetation loss. The lack of adequate planning has resulted in the encroachment on green spaces, with many areas being developed without consideration for environmental conservation. This has led to the fragmentation of ecosystems and the loss of critical habitats.

Poor urban planning is a significant challenge in many developing cities, where rapid urbanization often outpaces the capacity of local governments to manage growth sustainably (Emmanuel, 2007). In Kigali, the lack of integrated planning has resulted in the loss of green spaces and increased vulnerability to environmental hazards (REMA, 2015).

Impact on Environmental Resilience

The loss of vegetation in Kigali City has had a significant impact on the city’s resilience to environmental hazards. The majority of respondents (84%) reported that urban expansion

has decreased resilience, while a smaller percentage (16%) noted that some measures, such as wetland rehabilitation and tree planting, have improved resilience (Angel *et al.*, 2016). Below is a detailed analysis of these impacts.

Table 3: Impact of Change Urban Expansion on Environmental Resilience

Impact	Percentage of Respondents
Decreased Resilience	84%
Increased Resilience	16%

Source: *Primary data, 2025*

Explanation: This table visually represents the majority of respondents who believe urban expansion has decreased resilience, with a smaller percentage noting increased resilience.

Decreased Resilience (84%)

Most respondents agreed that the loss of vegetation has reduced Kigali’s resilience to environmental hazards such as flooding, landslides, and extreme weather events. Vegetation plays a crucial role in regulating water cycles, preventing soil erosion, and mitigating the urban heat island effect. The reduction in green spaces has made the city more vulnerable to these hazards, particularly in areas with steep terrain (Habimana, 2016).

The loss of vegetation has been linked to increased vulnerability to environmental hazards in many urban areas, particularly in cities with steep terrain like Kigali (UN-Habitat, 2013). The reduction in green spaces has also contributed to the urban heat island effect, where urban areas experience higher temperatures than their rural surroundings (Zhang, 2022).

Increased Resilience (16%)

A smaller percentage of respondents noted that some measures, such as wetland rehabilitation and tree planting, have improved the city’s resilience. These efforts have helped to restore some of the ecosystem services provided by vegetation, such as water filtration and climate regulation.

Official said that urban expansion has increased resilience in some areas, particularly through the

implementation of the Kigali Master Plan and zoning regulations.

Green infrastructure, such as wetlands, urban forests, and green roofs, have been shown to enhance urban resilience by providing ecosystem services that mitigate the impacts of environmental hazards (World Bank, 2017). In Kigali, the government’s efforts to promote green infrastructure are a positive step, but more needs to be done to scale up these initiatives (Kigali Master Plan 2050).

Effectiveness of Current Policies

The effectiveness of current policies aimed at protecting vegetation loss is a crucial aspect of sustainable urban and rural development. Vegetation loss, often driven by urbanization, deforestation, agriculture, and climate change, can have significant negative consequences on ecosystems, biodiversity, air quality, water cycles, and local climate (Angel *et al.*, 2012).

Discussion of Policy Effectiveness

The findings highlight the importance of not only designing effective policies but also ensuring their implementation and enforcement. While Rwanda’s urban planning policies are well-regarded (Seto, 2011), the lack of enforcement has limited their effectiveness in protecting vegetation and promoting sustainable development. To address this issue, the following measures are recommended:

Strengthen Enforcement Mechanisms: The government should invest in stronger enforcement

mechanisms to ensure that urban planning policies are implemented effectively.

Increase Community Awareness: Raising awareness about the importance of environmental conservation can help to build public support for the enforcement of policies (Angel *et al.*, 2022).

Promote Participatory Planning: Involving local communities in the planning process can help to ensure that policies are aligned with the needs and priorities of residents.

The effectiveness of current urban planning policies in promoting sustainable development and environmental conservation was a key focus of the study. While 60% of respondents believe that current policies are effective, 40% criticized the lack of enforcement, particularly in relation to environmental conservation. Below is a detailed analysis of these findings.

Effective (60%)

A majority of respondents believe that current urban planning policies are effective in promoting sustainable development. These policies include the Kigali Master Plan 2050, which outlines a vision for the city's growth, and the Green Growth and Climate Resilience Strategy, which emphasizes the importance of environmental conservation.

Most respondents believe that current policies can be respected and implemented like the Kigali Master Plan and zoning regulations to address vegetation loss. They noted that current policies are very effective but highlighted challenges

related to population growth and violations of green space regulations.

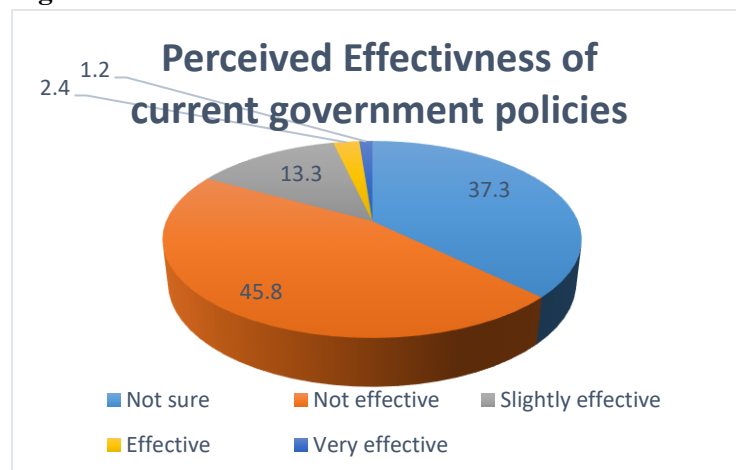
Specialist highlighted the importance of not only designing effective policies but also ensuring their implementation. The challenges identified such as population growth and violations of green space regulations, underscore the need for stronger enforcement mechanisms and community engagement.

Rwanda's national development strategies, such as Vision 2050 and the Green Growth and Climate Resilience Strategy, have been praised for their focus on sustainable development and environmental conservation (REMA, 2015). However, the effectiveness of these policies depends on their implementation and enforcement (Kigali Master Plan 2050).

Not Effective (40%)

A significant percentage of respondents criticized the lack of enforcement of existing policies, particularly those related to environmental conservation. They noted that while the policies are well-designed, they are not always implemented effectively, leading to the continued loss of green spaces.

The gap between policy and practice is a common challenge in many developing countries, where weak enforcement of regulations often undermines the effectiveness of well-designed policies (Emmanuel, 2007). In Kigali, the lack of enforcement has been a major barrier to achieving sustainable urban development (REMA, 2015).

Figure 6: Perceived Effectiveness of Current Urban Planning Policies

Source: Primary data, 2025

Explanation: This pie chart visually represents the majority of respondents who believe current policies are effective, with a significant percentage criticizing their enforcement.

CONCLUSION

This study has provided valuable insights into the spatiotemporal changes in urban expansion and vegetation cover in Kigali City. The findings highlight the complex interplay of demographic, economic, and policy-related factors driving urban expansion, as well as the significant environmental impacts of vegetation loss. The study underscores the need for sustainable urban planning that balances development with environmental conservation. By integrating green infrastructure into urban planning, strengthening policy enforcement, promoting community engagement, and adopting sustainable development practices, Kigali can achieve a model of urban expansion that is both sustainable and inclusive.

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