Journal of Agriculture & Environmental Sciences

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ISSN: 2616 - 8456

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture & Environmental Sciences
Volume 9||Issue 1||Page 89-104 ||April||2025|
Email: info@stratfordjournals.org ISSN: 2616-8465

Impact of Informal Settlement on Land Use Land Cover Change in Rwanda, a Case of Gahanga Sector in Kicukiro District, Rwanda

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***How to cite this article*: Twagirimana D., Nsanzumukiza M., V., Mupenzi C., Habingabire J., B., & Ntawuhongerumwanzi C. (2025). Impact of Informal Settlement on Land Use Land Cover Change in Rwanda, a Case of Gahanga Sector in Kicukiro District, Rwanda. *Vol* 9(1) pp. 89-104. https://doi.org/10.53819/81018102t2474**

Abstract

This study investigated the impact of informal settlements on Land Use Land Cover (LULC) change in Gahanga Sector, Kicukiro District, Rwanda. Using GIS and Remote Sensing techniques with Landsat imagery from 2010, 2016, 2020, and 2024, LULC changes were analyzed through ENVI 5.3 to map informal settlements and environmental changes. Seven LULC classes were assessed: informal and planned settlements, farmland, bare land, forest, marshland, and water bodies. The study focused on farmland decline, deforestation, vegetation loss, and wetland shrinkage. Findings aim to inform policymakers and urban planners on sustainable strategies to manage urbanization and mitigate environmental impacts in developing areas. The results indicated that within the period of 14 years, informal settlement decreased to 2.42% while planned settlement increased at 5.05%. Forest cover decreased to 9.43%, farmland decreased to 6.05% and bare land increased to 18.39% due to the development of earth roads by urban physical land use planning and extraction of construction materials. Land Cover fragmentation due development of informal settlement and its conversion to planned settlement from 2010 to 2024 lead to the vulnerability of Nyabarongo marshland and water body in Gahanga Sector of Kicukiro district in the City of Kigali, Rwanda. Marshland laid area reduced to 10.11% due to water flooding which increased to 3.56%. This led to the conclusion that to eliminate informal settlement and its impacts to Land Use Land Cover Change resulting to environmental degradation in Gahanga sector requires continuous enforcement of Kigali city masterplan 2020 implementation and community mobilization on environmental conservation, sustainable urban development, and formal construction permitting scheme.

Key words: *Informal settlement, Land Use Land Cover Change, Environmental impact, GIS, Kicukiro District, Gahanga Sector, Rwanda.*

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Journal of Agriculture & Environmental Sciences
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1. Introduction

The expansion of informal settlements has emerged as a significant driver of Land Use Land Cover (LULC) change, particularly in rapidly urbanizing regions of the world. As cities grow under the pressure of rural-to-urban migration, the demand for affordable housing frequently outpaces the capacity of formal urban planning systems to respond effectively. In the absence of adequate housing and infrastructure, informal settlements often develop spontaneously and unregulated, reshaping the physical and environmental structure of urban landscapes (UN-Habitat, 2016).

Globally, informal settlements have become defining features in urban centers across Asia, Latin America, and parts of Eastern Europe. These settlements typically lack basic services such as water supply, sanitation, waste management, and legal land tenure. Their growth often results in the unplanned conversion of green spaces, forests, agricultural land, and wetlands into densely populated residential areas. This leads to fragmented land use patterns and the degradation of ecosystems, significantly impacting urban sustainability and resilience (Woldegerima et al., 2017).

In Africa, the phenomenon is particularly pronounced due to the continent's high rates of urban growth and relatively weak governance structures. Sub-Saharan African cities such as Nairobi, Lagos, and Kinshasa face immense challenges in regulating land use and implementing inclusive urban development strategies. Research by Mahabir et al. (2016) and Kuffer et al. (2020) highlights how informal settlements in African cities often expand into ecologically sensitive zones, disrupt natural drainage systems, and intensify environmental risks such as flooding and soil erosion. These developments reflect not only physical land transformations but also deeper socio-economic inequalities, institutional weaknesses, and the need for more responsive urban policies.

The proliferation of informal settlements, often referred to as slums poses significant challenges to sustainable urban development in Rwanda. Rapid urbanization, coupled with factors such as rural-to-urban migration, limited land availability, and inadequate housing policies, has led to the emergence of informal settlements on the outskirts of major cities like Kigali. These settlements are characterized by overcrowded living conditions, inadequate infrastructure, and a lack of basic services such as water, sanitation, and waste management (UN-Habitat, 2019).

Informal settlements in Rwanda are rapidly transforming land use and land cover, particularly in urban and peri-urban areas. These unplanned developments often replace agricultural land, forests, and wetlands with dense built-up areas, leading to habitat loss and landscape fragmentation. Their irregular growth patterns pose challenges for sustainable urban planning and land management (Mahabir et al., 2016). Moreover, deforestation and land degradation often occur as residents seek fuelwood and expand settlement areas into natural habitats, disrupting fragile ecosystems and reducing biodiversity (GIZ, 2017).

Addressing the complex interplay between informal settlements and Land Use Land Cover Change requires comprehensive strategies that integrate urban planning, environmental management, and community development efforts. While the Rwandan government has made strides in promoting sustainable urban development through initiatives such as the Kigali Master Plan and slum upgrading programs, significant challenges remain in ensuring inclusive and equitable access to basic services and infrastructure for residents of informal

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settlements (Ministry of Infrastructure Rwanda, 2020). Moreover, effective implementation of policies and interventions necessitates strong governance mechanisms, community participation, and multi-stakeholder collaboration to address the root causes of informal settlements and mitigate their adverse environmental impacts (World Bank, 2019).

1.1 Research Objectives

1.1.1 General objective

The general objective of this study is to assess the impact of informal settlement on Land Use Land Cover Change in Rwanda with specific reference of Gahanga Sector in Kicukiro District of Kigali City

1.1.2 Specific objectives

The specific objectives of this study are the followings:

(i) To Assess the extent of informal settlements in Gahanga Sector.
(ii) To Assess the level of Land Use Land Cover Change in Gahanga Sector
(iii) To Assess the impact of informal settlement on Land Use Land Cover Change in Gahanga Sector.

2. Materials and methods

2.1 Profile of Kicukiro District

The study was conducted in Kicukiro District, one of the 30 districts of Rwanda and one of the three districts that make up the City of Kigali, the nation's capital. Kicukiro District comprises ten sectors: Gahanga, Gatenga, Kigarama, Gikondo, Kagarama, Niboye, Kicukiro, Kanombe, Nyarugunga, and Masaka. It spans an area of 166.7 km² and includes 41 cells and 327 villages. According to the Fifth Rwanda Population and Housing Census (RPHC, 2022), Kicukiro District has a population of 491,731, with a population density of 2,944 inhabitants per km², making it the most densely populated district in Kigali. The district is home to 135,463 private households, with an average household size of 3.6 persons. This demographic pressure contributes significantly to the demand for land and urban infrastructure, often resulting in the emergence of informal settlements, especially in rapidly urbanizing areas.

The most common type of housing in Kicukiro is modern planned urban housing, accounting for 61.8% of all residences, followed by spontaneous or squatter housing at 28.4%. However, the distribution of housing types varies by sector, with areas like Niboye, Nyarugunga, Kanombe, and Masaka showing higher percentages of modern planned housing. Gikondo and Gahanga report lower rates of such housing, with Gikondo having only 21.9% and Gahanga 42.6%. In terms of energy use for cooking, charcoal is the dominant source (57.4%), followed by gas (26.2%) and firewood (13.6%).

Gahanga Sector, the specific focus of this research, is the largest and most populous sector in Kicukiro, with 79,082 residents living in six cells: Karembure, Kagasa, Murinja, Nunga, Gahanga, and Rwabutenge. Covering 36.77 km², Gahanga has 22,883 households, with an average household size of 3.5. Notably, 49.3% of housing in Gahanga is spontaneous or squatter housing, while only 42.6% is modern planned housing. The sector has no rural area or

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Umudugudu settlements, highlighting its fully urbanized nature. The figure below shows the map of the study area.

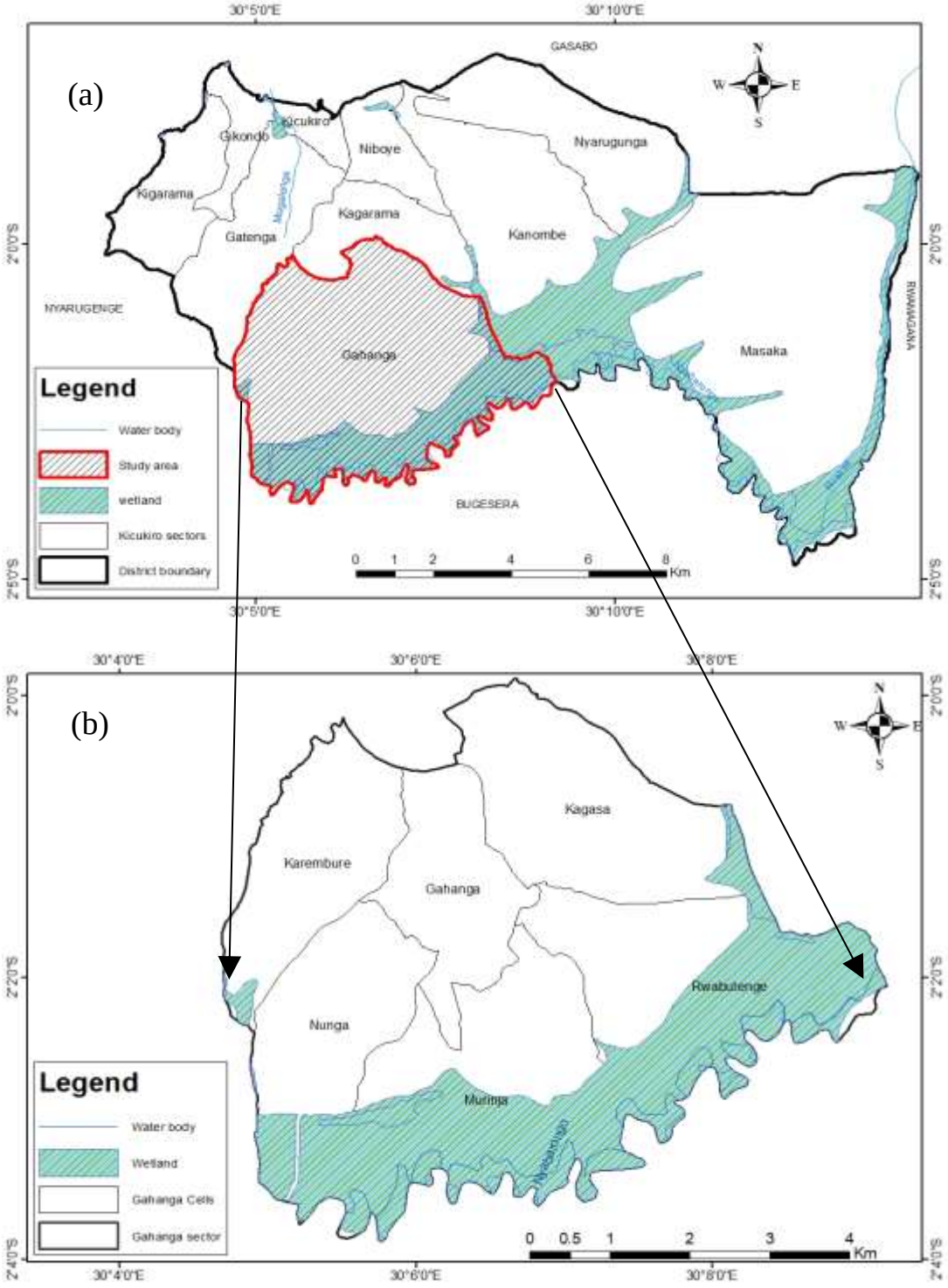

Figure 3. 1: Map of the study area: Kicukiro district (a), and Gahanga sector (b).
Source: Researcher, 2025.

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2.2 Research design and data collection methods

The research adopted a mixed-methods design, integrating both quantitative and qualitative approaches to provide a comprehensive analysis of informal settlement patterns and land use and land cover (LULC) changes in Gahanga Sector. This methodological approach, as supported by Silverman (2011), allows for the detection of relationships among variables, enhances the depth of findings, and ensures the research effectively addresses its objectives while minimizing potential errors. The quantitative component relied heavily on geospatial technologies, particularly Remote Sensing (RS) and Geographic Information System (GIS), to map and quantify changes in LULC over a period spanning from 2010 to 2023. Statistical models were developed using satellite data to analyze correlations between the expansion of built-up areas and LULC transitions. On the other hand, the qualitative component included field observations and expert interviews that provided critical contextual understanding and helped validate geospatial findings. This blend of methods ensured a robust framework for analyzing how human-environment interactions, particularly informal settlement developments, influence spatial and environmental dynamics in Gahanga.

The research relied on both primary and secondary data to ensure the accuracy and reliability of findings. Secondary data included satellite imagery, specifically Landsat datasets obtained from reputable providers like the United States Geological Survey (USGS), and GIS shapefiles that demarcated study boundaries. These datasets enabled the researcher to map various land cover categories, including informal and planned settlements, forested areas, farmlands, wetlands, bare lands, and water bodies. In complement, primary data were collected through structured field observations. These observations aimed to validate satellite interpretations and provided firsthand evidence of the environmental impacts of informal settlements. Walkthrough surveys were conducted across various informal settlements within Gahanga Sector to document visible signs of land degradation, such as deforestation, erosion, pollution, and wetland encroachment. A structured checklist guided these observations to ensure systematic data collection.

GIS and RS techniques were integral in data collection and processing, providing a visual and analytical platform for detecting LULC changes and the extent of informal settlements. Satellite imagery underwent geometric correction using topographic maps and ground control points to ensure positional accuracy. The processed data were analyzed using ArcGIS and ENVI software for mapping, while Microsoft Excel was used to generate statistical tables and graphs that presented trends and patterns over time. Ethical standards were strictly followed throughout the study. All geospatial data were obtained legally, and fieldwork was conducted with respect for local communities, ensuring that informed consent was secured when necessary and confidentiality maintained. The integration of multiple validated data sources and the triangulation of results strengthened both the validity and reliability of the research outcomes.

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2.3 Illustration of research methodology

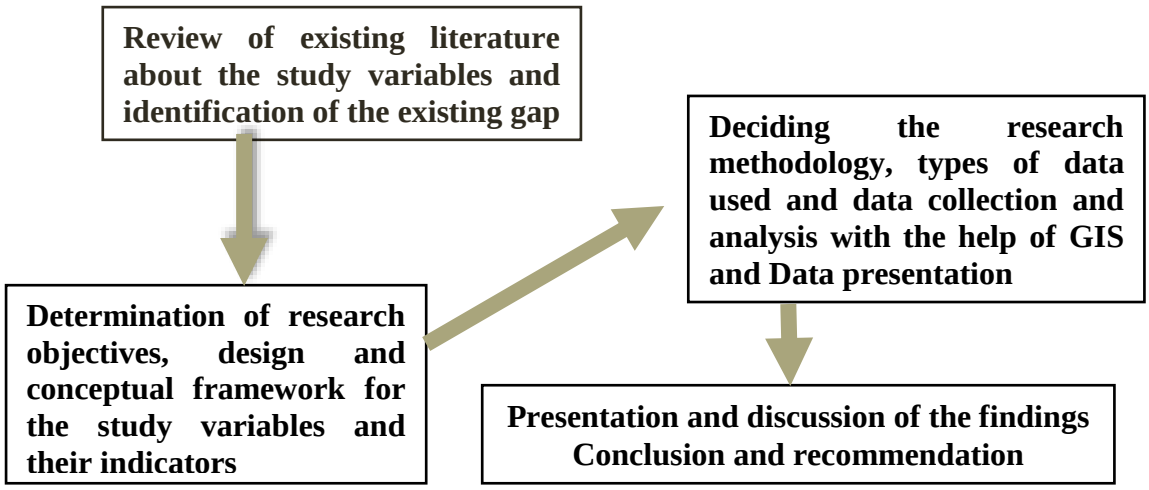

Figure 2.1: Methodology flowchart followed by the researcher

3. Results

3.1 Assessment of the extent of informal settlements in Gahanga Sector

Land use and land cover processing and analysis over a certain period give insights using earth observation techniques on the extent of expansion of informal settlement versus planned settlement in Gahanga sector. The analysis of satellite image gives real time data to detect Land Use Land Cover Change. For this purpose, the seven courses of LULC are selected in the study region such as informal settlement, planned settlement, Farmland, Bare land, Forest, Marshland and Water body. The study covered the 6 cells of Gahanga sector: Gahanga, Kagasa, Karembure, Nunga, Murinja and Rwabutenge. The Figure 3.1. illustrates land use land cover sensed by satellite on 07th of July 2010.

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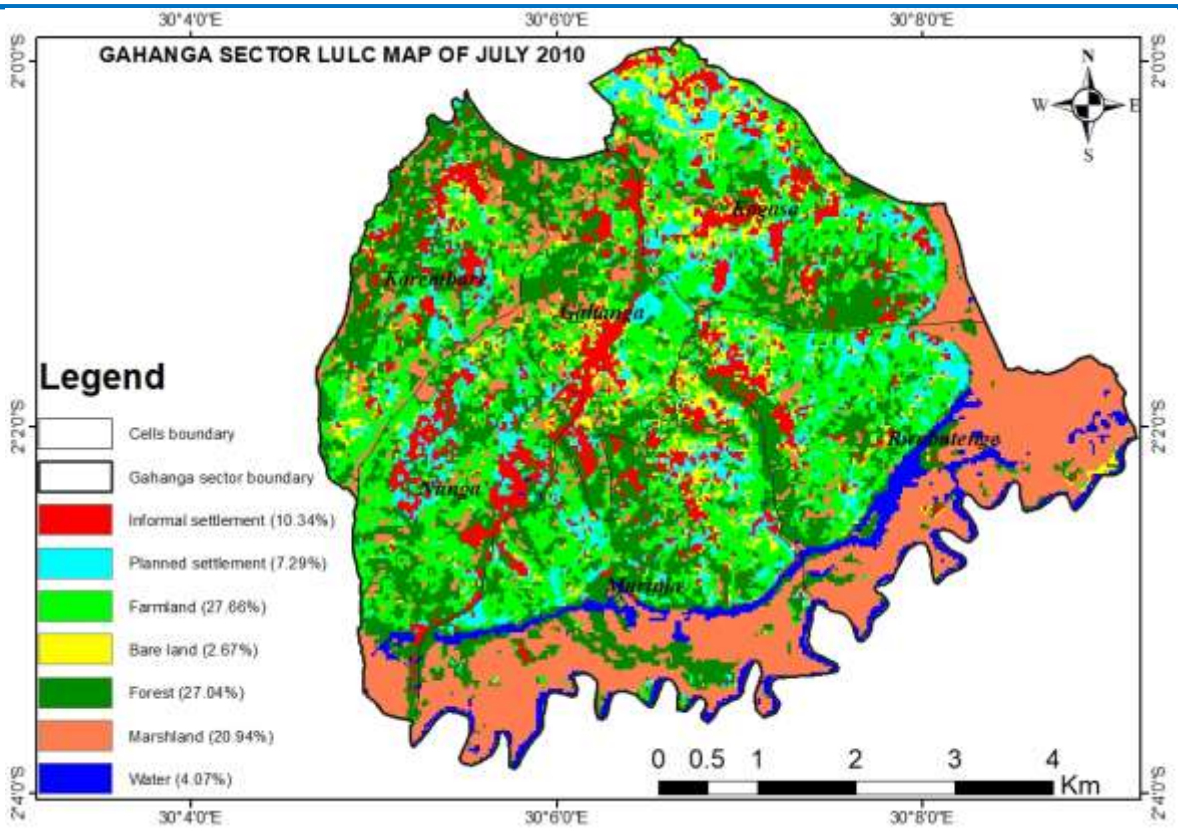

Figure 3.1.Gahanga sector LULC of July 2010

Source: Researcher, 2025

The results represented in Figure 3.1. indicated that in July 2010 the Informal settlement in Gahanga sector occupied 10.34%; Planned settlement (7.29%); Forest 18.57%; Farmland (27.66%); Bare land 2.67%; Marshland laid on 20.94%; and marshland water including Nyabarongo river water were at 3.07%.

The Figure 3.2. illustrates land use land cover sensed by satellite on 28th of June 2016. The results represented in Figure 3.2. indicated that in June 2016 the Informal settlement in Gahanga sector occupied 12.00%; Planned settlement (6.76%); Forest 22.15%; Farmland (25.08%); Bare land 9.36%; Marshland laid on 18.72%; and water in marshland including Nyabarongo river water were spread at 5.92%.

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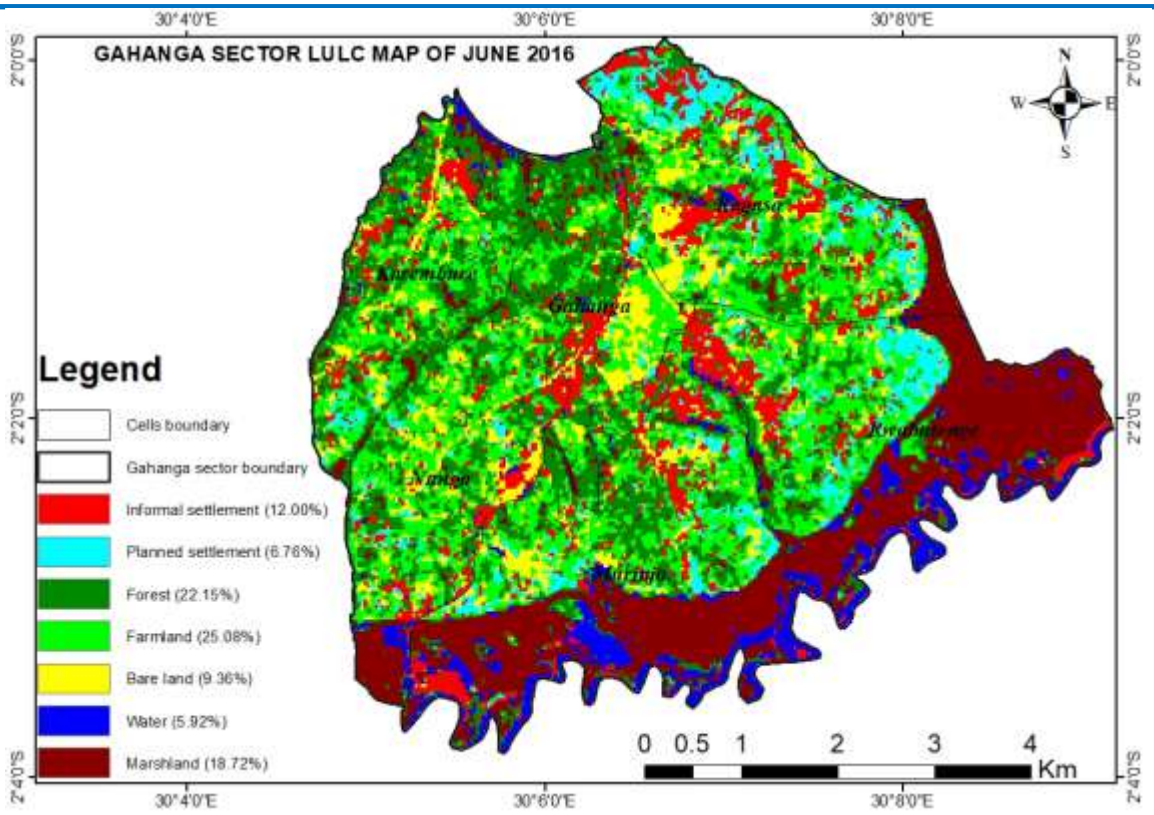

Figure 3.2. Gahanga sector LULC of June 2016

Source: Researcher, 2025

In the Figure 3.2, it was noted that informal settlement increased from 10.3% to 12.00%; while planned settlement decreased from 7.29% to 6.76% in 2016 compared to 2010.

The Figure 3.3. illustrates land use land cover sensed by satellite on 07th of July 2020. The results represented in Figure 3.3. indicated that in July 2020, the Informal settlement in Gahanga sector occupied 9.55%; Planned settlement (8.07%); Forest 23.81%; Farmland (23.19%); Bare land 13.71%; Marshland laid on 13.65%; and marshland water including Nyabarongo river water were at 6.01%.

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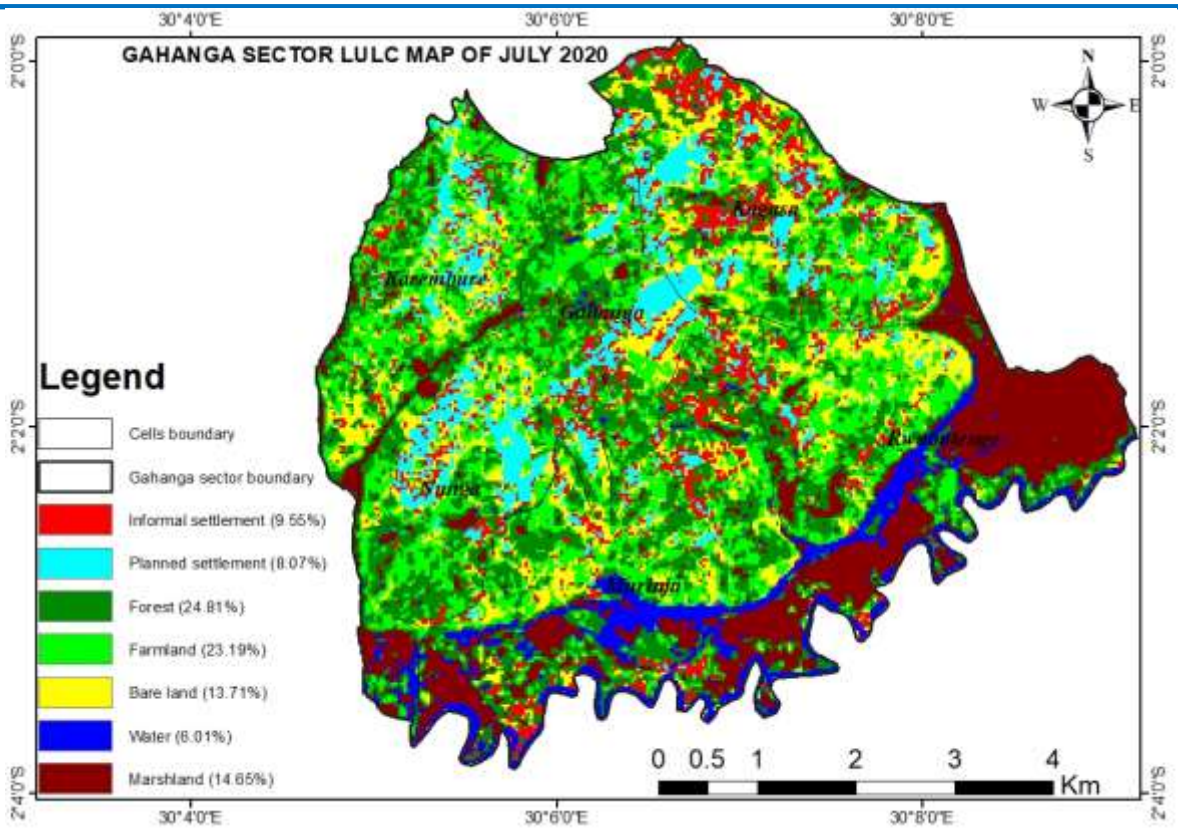

Figure 3.3. Gahanga sector LULC of July 2020

Source: Researcher, 2025

From the Figure 3.3, it was noted that informal settlement decreased from 12.00% to 9.55%; while planned settlement increased from 6.76% to 8.07% within the period of 4 years, from June 2016 to July 2020.

The Figure 3.3. illustrates land use land cover sensed by satellite on 05th of August 2023. The results presented in Figure 3.4 illustrate the land use distribution in Gahanga sector as of August 2023. Farmland occupied the largest share at 21.61%, followed closely by bare land at 21.06%, indicating a mix of productive agricultural activity and underutilized land. Forested areas accounted for 17.61%, reflecting a focus on environmental conservation, while marshlands and water bodies, including the Nyabarongo River, represented 10.83% and 8.63%, respectively, underscoring their ecological significance.

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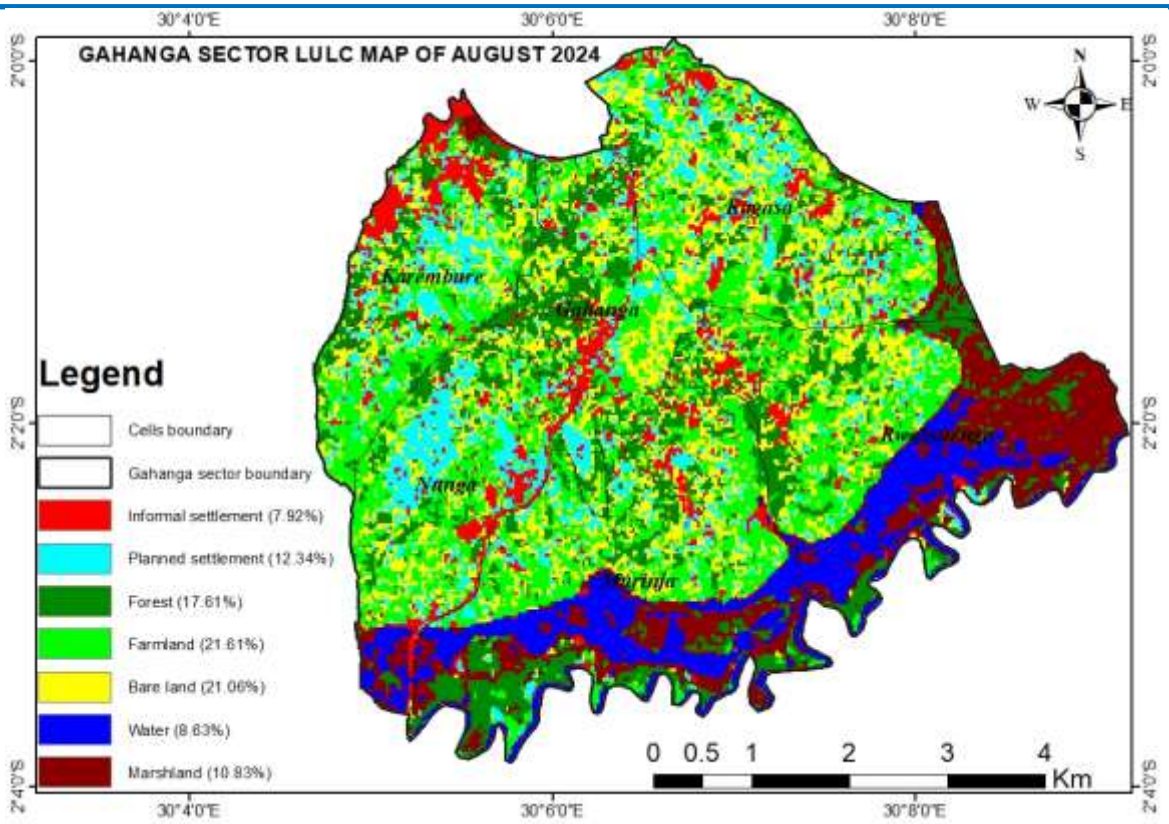

Figure 3. 4.Gahanga sector LULC of August 2024

Source: Researcher, 2025

Settlements exhibited notable changes over the four-year period from July 2020 to August 2023. Informal settlements decreased from 9.55% to 7.92%, suggesting progress in controlling unplanned urban growth, while planned settlements increased significantly from 8.07% to 12.34%, highlighting improvements in urban planning and infrastructure development. This shift indicates a positive trend toward organized development, emphasizing a balance between urbanization, agricultural productivity, and environmental preservation.

3.2. The assessment of the level of Land Use Land Cover Change in Gahanga Sector

In order to assess expected changes in natural environment, the researcher has collected and analyzed the baseline information about the current situation in the study area. The urban development of an area has all the time the negative and positive environmental impacts in general because whatever is done, there is a change to the nature of environment.

In case of shifting from informal to planned settlement in Gahanga sector, the developers have to set out the proper way for the implementation as part of other development projects in the country. In this study, the specific Land Use Land Cover components such as Farmland, Bare land, Forest cover, Marshland area and Water body were identified and assessed on their level of change from their natural status from 2010 to 2024, due to urban development vis à vis informal settlement and planned settlement in Gahanga sector.

The results of the study revealed that by the period of 14 years, there is a change of natural state of Land Use Land Cover components in the study area. Moreover, the informal

settlement has been reduced at 2.42% (i.e. from 10.34% in 2010 to 7.92% in 2024), while planned settlement has been developed at 5.05% (i.e. from 7.29% in 2010 to 12.34% in 2024). Therefore, this interchange between informal and planned settlement has been impacted negatively the forest cover at the decrease of 9.43% (i.e. from 27.04% in 2010 to 17.61% in 2024); farmland or cropland has been decreased at 6.05% (i.e. from 27.66% in 2010 to 21.61% in 2024). The bare land has been increased considerably at 18.39% in relation with planned settlement increase (i.e. from 2.67% in 2010 to 21.06% in 2024).

Marshland and water are correlated because if the quantity of water increase the area laid by marshland decrease. The results of the study indicated that from 2010 to 2024, the water flooded area has increased from 3.07% to 8.63%; while marshland area decreased from 20.94% to 10.83%.

3.3. The assessment of the impact of informal settlement on Land Use Land Cover Change in Gahanga Sector.

3.3.1. Farmland decline

The analysis of Land Use and Land Cover (LULC) changes in study area between 2010 and 2024 reveals a significant decline in farmland, which is closely linked to the expansion of human settlements. Among the seven identified LULC classes informal settlement, planned settlement, farmland, bare land, forest, marshland, and water body farmland has experienced a consistent decrease in area over the years.

In the initial period from 2010 to 2016, informal settlements expanded from 10.34% to 12%, while farmland declined from 27.66% to 25.08%. This 2.58% decrease in farmland is largely attributed to the encroachment of informal settlements, which often develop without proper spatial planning, leading to the conversion of arable land into residential zones.

The transition is observed from 2010 to 2024, where informal settlements reduced from 10.34% to 7.92%, suggesting a shift toward planned development. During the same period, planned settlements increased significantly from 7.29% to 12.34%, reflecting government efforts to regulate urban growth. However, farmland continued to decline sharply, falling to 21.61% by 2024, a total decrease of 6.05% over 14 years.

This ongoing reduction in farmland area has considerable implications on local agricultural productivity, food security, and rural livelihoods. As farmland shrinks, the ability to provide essential services such as food supply, employment, and ecological balance is diminished.

3.3.2. Deforestation and loss of vegetation

Land Use and Land Cover (LULC) analysis in the study area from 2010 to 2024 shows a concerning trend of deforestation and general vegetation loss, closely associated with the expansion of settlements and increased land degradation. The LULC categories considered include informal settlement, planned settlement, farmland, bare land, forest, marshland, and water body.

Between 2010 and 2016, informal settlements expanded from 10.34% to 12%, while forest cover declined from 27.04% to 22.15%. This deforestation is largely linked to the

unregulated spread of informal settlements, which often results in the clearing of forested areas to accommodate housing and associated activities. In parallel, bare land significantly increased from 2.67% to 9.36%, indicating a loss of vegetative cover beyond forests, potentially including shrublands and grasslands.

From 2010 to 2024, the trend shifted as informal settlements reduced from 10.34% to 7.92%, while planned settlements increased from 7.29% to 12.34%, reflecting a transition toward more structured urban development. However, forest cover continued to decline drastically, reaching 17.61% by 2024, marking a total loss of 9.43% over the 14-year period. Similarly, bare land surged further to 21.06%, representing a dramatic expansion that underscores a broader vegetation loss in the region.

The ongoing decline in forest cover has serious implications for biodiversity, carbon sequestration, microclimate regulation, and other ecosystem services provided by forests. Meanwhile, the increase in bare land signifies not only deforestation but also the degradation of other vegetative landscapes, which affects soil fertility, water retention, and overall land productivity.

3.3.3. Wetland shrinkage

The Land Use and Land Cover (LULC) analysis conducted in Gahanga Sector from 2010 to 2024 highlights a significant reduction in marshland areas, a trend closely associated with the growth of settlements and changes in hydrological dynamics. Among the seven key LULC classes which are: informal settlement, planned settlement, farmland, bare land, forest, marshland, and water body; marshland showed one of the most notable declines.

Between 2010 and 2016, informal settlements increased from 10.34% to 12%, while marshland areas decreased from 20.94% to 18.72%. This reduction is accompanied by a rise in water body coverage from 3.07% to 5.92%, indicating potential changes in surface runoff and local flooding patterns. The expansion of informal settlements often lacking proper drainage and flood control infrastructure has contributed to increased water discharge into wetland zones. This has led to wetland inundation and degradation, reducing the ecosystem's ability to perform its vital functions.

In the period from 2010 to 2024, a transition from informal to planned settlement is observed. Informal settlements decreased from 10.34% to 7.92%, while planned settlements increased from 7.29% to 12.34%, reflecting a move toward more structured development. Despite this shift, marshland continued to shrink significantly, dropping from 20.94% in 2010 to 10.83% in 2023. Over the 14-year study period, total marshland cover declined by 10.11%. Simultaneously, water bodies expanded further to 8.63%, reinforcing the idea that altered water flows and encroachment from settlements are major factors in wetland loss.

The shrinkage of wetlands poses serious threats to biodiversity, water purification, flood regulation, and local climate moderation. Wetlands serve as natural buffers in urban and peri-urban environments, and their loss compromises not only environmental sustainability but also human resilience to climate variability.

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3.5. Discussion of results

In Rwanda, construction without a permit is illegal and subject to enforcement actions by authorities. This practice undermines the rule of law and the regulatory frameworks established to ensure the safety, quality, and sustainability of built environments. Without proper oversight, unregulated construction activities can pose risks to public safety, compromise structural integrity, and contribute to informal settlements and Land Use Land Cover Change resulting to environmental degradation. According to the United Nations Human Settlements Programme (UN-Habitat), informal settlements are "areas where housing is developed in an unplanned and uncoordinated manner, often resulting in inadequate infrastructure and services, poor living conditions, and limited access to basic amenities" (UN-Habitat, 2003).

Urbanization, driven primarily by rural-urban migration, plays a major role in the growth of informal settlements (Turok, 2014). This study revealed that in 2010, informal settlements in Gahanga sector covered 10.34%, a higher rate compared to planned settlements at 7.29%. This finding aligns with Turok's argument, as Gahanga sector, with its extensive rural farmland, attracted immigrants from neighboring Bugesera district and peri-urban areas who settled there seeking employment opportunities and built houses without obtaining construction permits from the City of Kigali.

Duyan (2017) similarly noted that informal settlements often emerge as adaptive responses to changing socio-economic conditions, including rural-urban migration, population growth, and economic restructuring. The human ecology theory, as highlighted by Duyan, emphasizes the adaptive strategies used by residents of informal settlements to navigate urban challenges such as housing, water, sanitation, and livelihoods. Consistent with this theory, the study results showed that between 2010 and 2016, informal settlements increased from 10.34% to 12%, while planned settlements decreased from 7.29% to 6.76%. Hawley (1986) added that environmental factors, including land availability, topography, and climate, significantly influence settlement patterns and land use dynamics. This aligns with the study findings, which revealed that farmland decreased from 27.66% in 2010 to 25.08% in 2016 due to the expansion of built-up areas. Similarly, bare land increased from 2.67% to 9.36% during the same period, largely as a result of access roads developed to support urban growth in Gahanga sector.

UN-Habitat (2016) emphasized that promoting inclusive and sustainable economic development can help reduce the drivers of urban migration and address the root causes of informal settlement formation.

The Government of Rwanda has implemented various policies, legal, and regulatory frameworks aimed at environmental protection, sustainable development, and urban management, such as the Environmental Law (2018), National Land Policy (2019), Kigali City Master Plan (2020), and Land Law (2021). The impact of these measures is reflected in this study's results: by 2020, informal settlements began to decline to 9.55%, while planned settlements increased to 8.07%. This positive trend continued into 2024, with informal settlements decreasing further to 7.92% and planned settlements rising to 12.34% as of August 2023.

Further, Mwangi and Mutua (2015) examined the relationship between informal settlements and deforestation in Kenya, finding that rapid urbanization and population growth often lead to the clearing of forests for housing and agriculture. This study supports

their findings, showing a 9.43% reduction in forest cover and a 6.05% decrease in farmland between 2010 and 2024, driven by expanding informal settlements and built-up areas.

In addition, Adegun et al. (2020) used remote sensing and GIS techniques to assess land cover changes and environmental degradation caused by informal settlements in Nigeria. They reported significant losses in forests, wetlands, and agricultural land due to informal urbanization, driven by population pressures and inadequate urban planning. This study similarly applied remote sensing and GIS techniques to analyze land use and land cover changes, revealing excessive fragmentation and increased vulnerability of the Nyabarongo marshland and water body. These findings underscore the urgent need for consistent enforcement of the Kigali City Master Plan (2020) and community mobilization efforts to promote environmental conservation, sustainable urban development, and adherence to formal construction permitting processes.

3. Conclusion

This study examined the impact of informal settlements on Land Use Land Cover (LULC) changes in Gahanga Sector, Kicukiro District, using secondary data derived from satellite imagery collected in 2010, 2016, 2020, and 2024. The analysis focused on seven land cover classes: informal settlement, planned settlement, farmland, bare land, forest, marshland, and water body. The results showed a notable increase in informal settlements from 10.34% in 2010 to 12% in 2016, while planned settlements declined from 7.29% to 6.76%. This trend was attributed to rapid urban expansion, insufficient urban development inspections, and weak enforcement of building construction regulations. However, from 2020 to 2024, a reverse trend was observed as informal settlements began to decrease, influenced by the introduction and enforcement of various national policies and frameworks, including the Environmental Law (2018), the National Land Policy (2019), the Kigali City Master Plan (2020), and the Land Law (2021).

The findings suggest that the growth and decline of informal settlements are significantly affected by policy enforcement, urban planning quality, and community engagement. Therefore, eliminating the adverse effects of informal settlements on land use and environmental sustainability in Gahanga Sector requires a multi-dimensional approach. This includes the continued implementation of Kigali's Master Plan 2020, strengthening of building code enforcement, and sustained public awareness and community mobilization regarding sustainable urban development practices. Promoting planned settlement not only supports organized urban growth but also contributes to environmental conservation and climate resilience.

Therefore, considering the findings, I would like to first recommend the establishment of community-based monitoring systems that could enhance early detection and reporting of unauthorized construction activities. There should also be greater collaboration between urban planners, local authorities, and community leaders to ensure that physical development plans are inclusive and reflective of community needs. Promoting low-cost, sustainable building technologies can further support formal settlement expansion, particularly for low-income residents. Moreover, land use datasets should be periodically updated, and routine assessments conducted to inform data-driven decisions. Finally, enhanced coordination between institutions responsible for urban development, housing, and environmental conservation is necessary to align strategies and optimize resource utilization. These efforts will facilitate the development of resilient and sustainable urban settlements in Gahanga and similar urban areas.

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