



Assessment on the Impacts of Urbanization on Wetland. Case Study City of Kigali

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Abstract

Urbanization's impact on wetlands, a global concern, is explored through a case study in the City of Kigali, Rwanda. With rapid demographic growth and limited agricultural land, the city faces notable pressure on wetland ecosystems due to urban expansion. The study employs GIS, remote sensing, and secondary data sources to analyze changes from 2000 to 2023.

Kigali's wetland spatial distribution undergoes significant alterations, particularly between 2008 and 2018, attributed to human activities like agriculture and dam development. The overarching issue is understanding urbanization's impact on ecological and socio-economic well-being in Kigali.

Data collection involves library and online research, coupled with spatial data analysis techniques. Urbanization changes reveal a marked increase in built-up areas, impacting agriculture and forests. Encroachment on wetlands intensifies from 2000 to 2023, with agricultural land diminishing and built-up areas expanding, posing a threat to wetland ecosystems.

Urbanization effects on Kigali's wetlands are diverse, including habitat loss, water quality degradation, disrupted hydrological processes, and biodiversity decline. Challenges identified range from wetlands being used as dumping sites to resource

exploitation and negative impacts of industrial development.

To counter these effects, the study proposes sustainable urban planning, strict regulations, public awareness, wetland restoration, stormwater management, collaboration, economic incentives, and long-term monitoring. Striking a balance between urban development and wetland conservation is crucial.

Existing policies governing wetland management in Rwanda are recognized, but strict implementation is crucial. The Rwandan government has established laws and policies, yet their effectiveness hinges on rigorous enforcement.

In conclusion, the research provides insights into the complex interplay between urbanization and wetland ecosystems in Kigali. By analyzing changes, identifying challenges, and proposing solutions, the study contributes to sustainable urban development and environmental conservation. The findings offer guidance for policymakers, environmentalists, and communities to collaboratively navigate urban growth and wetland preservation in Kigali and beyond.

Keywords: Wetland, Urbanization, Urban Wetland

1. Introduction

World population is continuously and rapidly growing whereby people are mostly migrating from Rural to urban which result in a high level of urbanization. Urbanization refers to the process whereby a society changes from a rural to an urban way of life (Andreea, 2020). Barman (2021) stated that the development in the urban area leads to the loss of wetlands more than 60%. Wetlands are a transitional area between aquatic ecosystem and terrestrial ecosystem that is inundated or saturated with water for a long enough period to produce hydric soil and support hydrophytic vegetables (Chen et al ,2010).

In the world countries, urbanization is the main root cause of urban wetland disturbances whereby Urbanization impacts urban wetland direct or indirect ways through converting wetland environment to other economic uses such constructions, mining, and quarrying activities. Disturbing the nature of the wetlands result in direct habitat loss, suspended solids additions, hydrological changes, loss of quality water, increased runoff volumes, diminished infiltrations to mention but few (Ajibola et al ,2012).

In Africa, wetlands constitute about 1 % of its total area, and they contribute significantly to the continent's biodiversity existence and population livelihoods. The greatest

concentration of wetlands occurs roughly between 15°N and 20°S, and it contains 4 main types namely; wetlands of the four major riverine systems (Nile, Niger, Congo and Zambezi); Lake Chad and wetlands of the inner Niger Delta in Malu, the Rift Valley lakes such as Victoria, Tanganyika, Nyasa, Turkana, Mweru and Albert); the Sudd in Southern Sudan and Ethiopia and the Okavango Delta in Botswana (Metz, 2017). All the wetland's present richness and exceptionality in biodiversity.

Rwanda is currently suffering from incredible pressure on agricultural land due to the rapid demographic growth and the limited availability of productive land. The rural population density has grown from 121 person's km⁻² in the 60's, to 262 in 1990, and to 380 person's km⁻² in 2010-, and 523.03-Kilometer square (NSR,2022).

The Rwandan government currently considers wetlands as a significant function for increasing food security and income through the production of rice and other commodities. In Rwanda the total area of wetland is 278536 ha (REMA, 2009). However, out of 148344 ha under cultivation in 2010, only 5000 ha are officially reclaimed, often with poor design and maintenance (Nabahungu and Visser, 2011b).

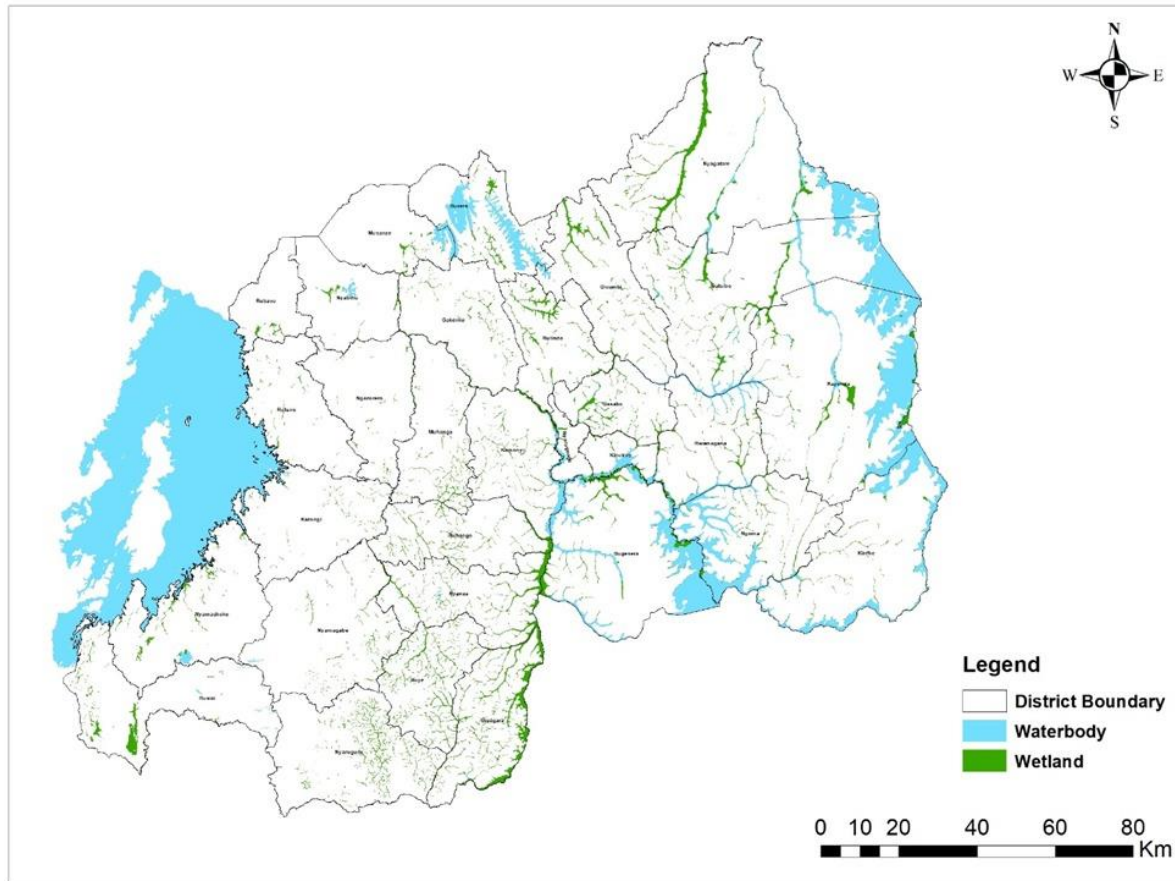


Figure 1. Wetland Spatial Distribution map

The rest is unofficially reclaimed, and a traditional farming system is practiced by farmers with the goal to provide family food security (Nabahungu and Visser, 2011a).

Wetlands cover types have changed dramatically during the previous 10 years (between 2008 and 2018) as a result of human activities, particularly irrigation and food security measures with expanded rice paddy and dam development. However, the situation was not frightening when compared to people's opinions of wetland reclamation over the previous two decades (ARCOS,2019).

It is true that wetlands protection has become a global issue. Three critical challenges concerning urban wetlands have been

identified through research. To begin, it has been claimed that over 50% of the world's wetlands as green areas have been steadily degraded (Ramirez & Fennell, 2014). Second, one of the underlying causes of this problem is that the general population is uninformed of the benefits of wetlands. In addition to this, the unplanned protection may lead to unsustainable exploitation and spontaneous development of natural wetlands (Wang, Yao, & Ju, 2008).

Increase in the population in urban areas has led to pressures to the urban areas ecosystem and contributed to the degradation of wetlands (Stella, 2010). Wetlands are important natural resources that offer a variety of ecosystem services, such as flood control, biodiversity

preservation, water filtration, and cultural significance. On the other hand, wetland loss and degradation brought on by urbanization can have a negative effect on the environment and public health.

Rwanda, like many other developing countries, has experienced rapid urbanization in recent years, with the City of Kigali serving as the focal point of this urban growth. This urban expansion has brought about numerous changes in land use and infrastructure development, which have raised concerns about the consequences on the nation's wetland ecosystems.

The City of Kigali, as the capital and largest urban center in Rwanda, has witnessed significant urban development and population growth. This growth has resulted in increased demand for land, leading to the encroachment and conversion of wetland areas for various purposes, including housing, agriculture, and infrastructure development. Such actions can disrupt the delicate balance of wetland ecosystems, affecting water quality, natural habitat, and the overall resilience of the environment (REMA, 2015).

As other countries, Urbanization rate in Rwanda is rapidly growing especially in Kigali due to movement of people from different corners of the country to the City of Kigali. The development of Kigali has led to various human economic activities like residential expansion, industrial and commercial activities, mining, quarrying, agricultural to mention but few have contributed to the pollution of Kigali's wetlands (Nshogoza et al, 2022).

The overarching problem that needs to be addressed is to understand the impacts of urbanization on wetlands in the City of Kigali and to determine the extent to which these

changes are affecting the ecological and socio-economic well-being of the region.

2. Data and Methods

Research methodology refers to the principal procedures of logical thought processes, which are applied to the scientific investigation, thus the research methodology can be considered as the overall strategy to achieve the aim and objectives. On the other hand, the research methods are merely tools (Sutrisan, 2009). According to Kassu (2019), defines a research methodology as the path through which researchers need to conduct their research; it shows the path through which those researchers formulate their problems and objectives and present their result from the data obtained during the study period. It also involves investigation of methods for collecting and organizing data and conducting rigorous research. This chapter explains the methods used for data collection to achieve both general and specific objectives of the research.

3.1 Description of study area

Kigali is in the center of Rwanda; the area of Kigali city is approximately 730 square kilometers. The city is situated on several hills, with valleys and ridges in between. The city is divided into three administrative districts: Gasabo, Kicukiro, and Nyarugenge. Each district has its own unique characteristics, but all are interconnected and contribute to the overall fabric of Kigali. Kigali is home to several wetland areas equaling 32 wetlands that play a crucial role in the city's ecosystem and contribute to its environmental sustainability.

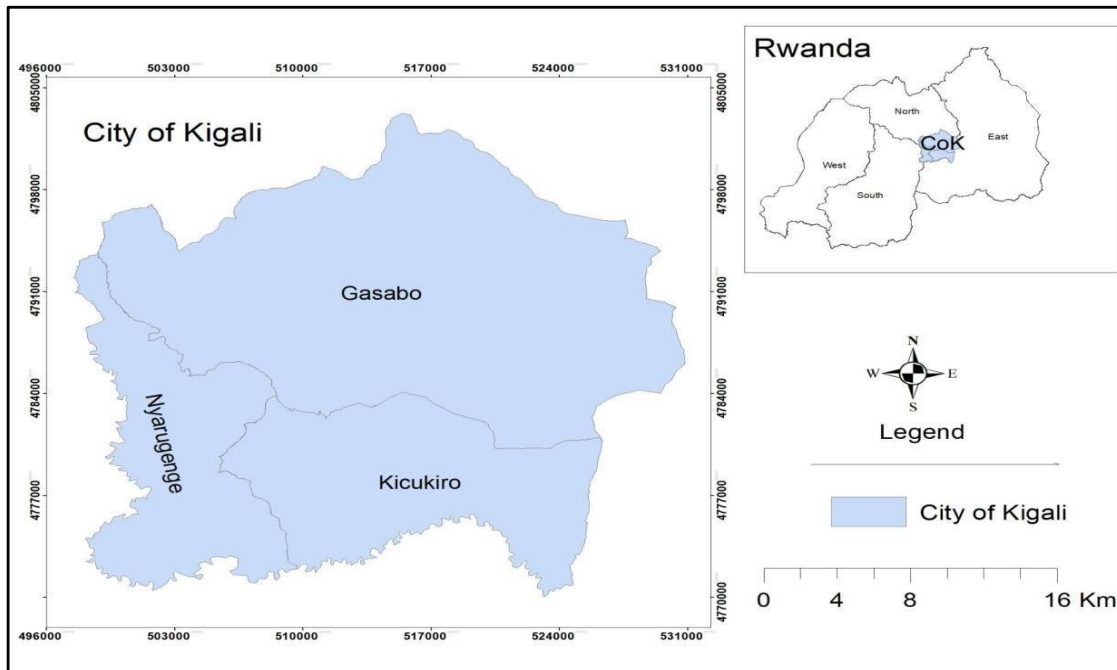


Figure 2. Location of City of Kigali

3.2 Data collection Methods

Data collection is the process of gathering and measuring information on variables of interest, in an established systematic fashion that enables one to answer state research questions, test hypotheses, and evaluate outcomes. Data collection is one of the most important stages in conducting research. You can have the best research design in the world but if you cannot collect the required data, you will not be able to complete your research. (S. Muhammad & S. Kabir, 2018). In this study, secondary data sources were used to achieve the research objectives.

3.2.1 Secondary Data collection

Victor Ajayi (2017) defines Secondary data as the data that have already been collected from primary sources and made readily available for researchers to use for their own

research, data which were collected by someone else earlier and made it available to be used by another researcher. Furthermore, secondary data collection sources are government publications, websites, books, journal articles and internal reports. In this research, we will use library research, online research and spatial data analysis to assess and analyze the impact of urbanization on the wetlands in the City of Kigali.

3.2.1.1 Library Research

Library research involves the step-by-step process used to gather information in order to write a paper, create a presentation, or complete a project. In the other words, library research seemed like on desk research. Whereby, data have been already collected and published are obtained through reviewing and retrieving different reading materials from both academic and scientific

libraries. In this research various books and previous final research projects related to our topic have been read in order to gather helpful information.

3.2.1.2 Online Research

Online research is the straightforward, assessing introduction to social research online. It also shows researchers how to engage in the online environment in innovative ways, and point the forward for the future research. (Tristraham Hooley, Jane Wellens & John Marriat, 2011). In Our research various published materials from the internet are used including articles, websites, online books, magazines, newspapers, and journals to define and understand different concepts related to land and land price variation.

3.2.1.3 Spatial Data Analysis

According Xiaoyi Ma & Tao Pei, (2012) defines spatial data analysis as a set of techniques to describe and visualize spatial distributions, discover patterns of spatial association, identify atypical observations and suggest different spatial regimes or other forms of spatial heterogeneity. Geographic information systems (GIS) are considered to perform basic functions on spatial data analysis such as; capture, input, store, analysis and output (S. Chatterjee, P. Shah, J. Dubey, 2010). In this research, GIS and Remote sensing data techniques will be used to provide information on urbanization changes in the last 23 years by detecting the change in land use land cover using satellite images, land use land cover classification will be used to detect the changes in land use in the city of Kigali. GIS software and technology will also be used to calculate and measure the level of the built-up activities and other human activities within the City of Kigali wetland's boundaries established by

the Prime Minister's order no 006/03 of 30/01/2017 drawing up a list of swamp lands, their characteristics and boundaries and determining modalities of their use, development and management.

3. RESEARCH FINDINGS

3.1. Detection of spatial and temporal urbanization changes in Kigali and activity encroaching wetlands in the last 23 years

3.1.1. Urbanization changes in Kigali from 2000 to 2023

Kigali, the capital city of Rwanda, has undergone a significant transformation in recent years due to urbanization. The city has experienced a rapid increase in population and a corresponding shift in its physical landscape by expanding in size, built up areas as well as in terms of infrastructures. Change in Urbanization has led to the construction of new residential, commercial, and industrial areas, resulting in the proliferation of buildings and infrastructure. This expansion has been particularly noticeable in the city center and surrounding neighborhoods.

In space and time, some major factors have been identified as the main drivers of urban growth in Rwanda, especially in Kigali City. These mainly include demographic, economic and biophysical factors as well as factors related to neighborhood and proximity characteristics. As far as demographic factors are concerned, the country's population has critically increased from 4.8 million in 1978, 10.5 million in 2012 to 13.3 million in 2022 and the percentage of the people living in

urban areas has also followed a similar trend (Rwanyiziri et al, 2020, NISR, 2022).

In 2000, built up areas had low coverage with 10.3 % of the total surface area and agriculture was the most leading land use with 80.9 % equaling 59279 ha. Rural to urban migration increased the Kigali's population and agricultural land was affected with other land uses. In this regard, built up areas increased up to 11.2% and 25.6 % in 2010 and 2020

respectively. However, due to various laws and regulations released for preserving and protecting the wetlands as well as regularizing building permits in Kigali, some buildings and industries in wetlands were destroyed and relocated which reduced built up areas by 24.1% in 2023.

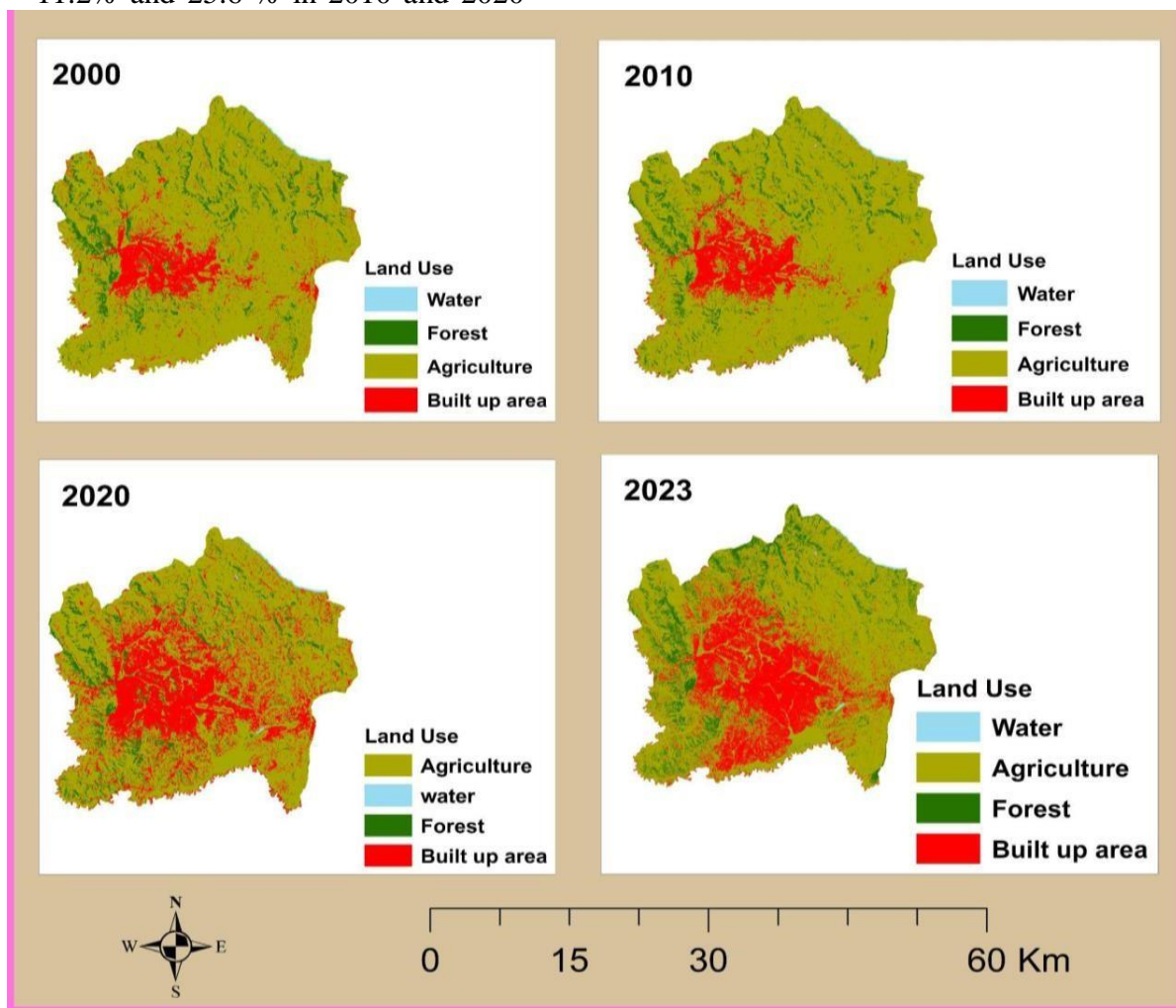


Figure 3. urbanization change in Kigali from 2000 to 2023

	2000		2010		2020		2023	
Land use	Area/ha	%	Area/ha	%	Area/ha	%	Area/ha	%
Agriculture	59279.6	80.9	59489.2	81.2	49167.03	67.1	47951.3	65.6
Built up area	7552.98	10.3	8226.3	11.2	18815.5	25.7	17842.3	24.4
Forest	6226.5	8.5	5305.05	7.2	5011.1	6.8	7111.4	9.7
Water	189.02	0.3	224.7	0.3	252.1	0.3	216.1	0.2

3.1.2 Human activities encroaching wetlands from 2000 to 2023

Human activities in Kigali have had a significant impact on wetlands in the area. Wetlands play a crucial role in maintaining ecological balance, providing important habitat for diverse plant and animal species, and offering various ecosystem services. However, the rapid urbanization and development in Kigali have resulted in the alteration and degradation of wetland areas in the last 23 years. As the Kigali city expands, wetlands have been encroached upon and converted into residential, commercial, and

industrial areas. Wetland areas have been drained and filled to make space for buildings and infrastructure, leading to the loss of wetland ecosystems.

Land uses with wetland boundaries have been changed as the urbanization changes in Kigali. In 2000, 89.3% of total surface area of wetland established by law was used for agriculture, 1.3 % for built up areas. In ten years, agricultural land has been reduced to 83.3 % and built-up areas with wetland boundaries increased to 10.6 % and 20.5% in 2010 and 2020. However, control measures have been taken to protect the wetland and all

buildings have been removed from wetlands boundaries that reduced built up areas from 20.5% in 2020 to 14.7% in 2023.

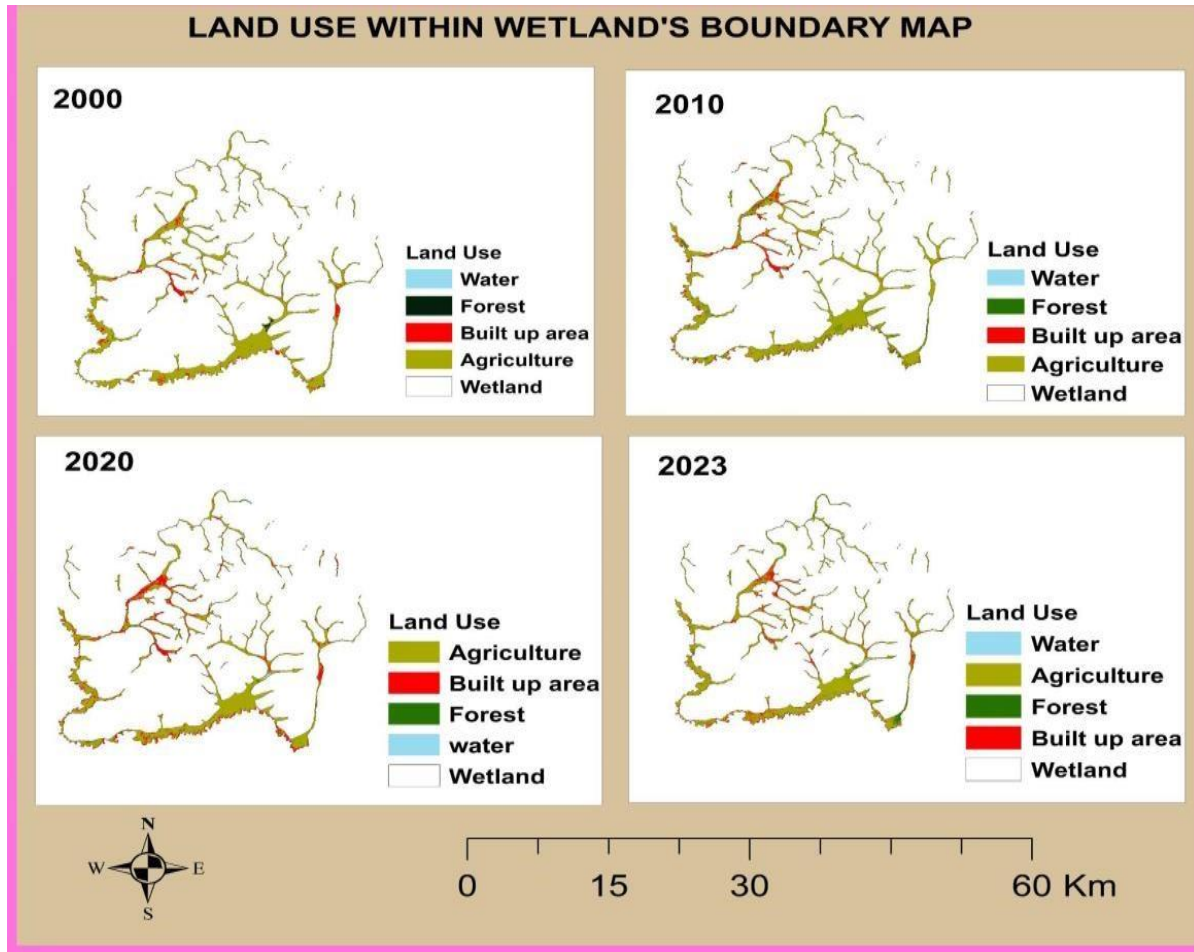


Figure 4. Land uses with wetland boundaries in the city of Kigali.

As indicated in the previous paragraphs, urbanization changes in Rwanda have gradually had serious effects not only on wetland resources, but also on other land use trends and land cover types. These effects are both positive like economic growth from the

exploitation of natural resources and negative like biodiversity loss, shrinkage of agricultural and forest lands, etc. By specifically using the image classification analysis of the available Landsat images for 4 different decades (2000, 2010, 2020, and 2023), it can be argued that urban growth has rapidly increased, leading to a gradual depletion of resources in wetland of City of Kigali.

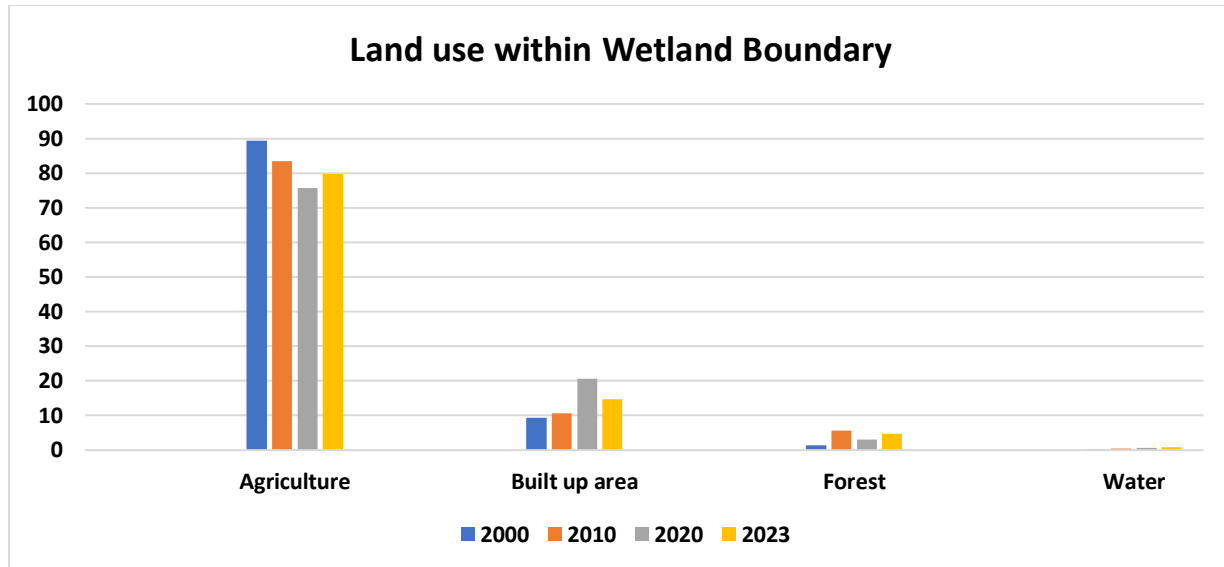


Chart 1. Land use changes with wetland boundaries from 2000-2023

As it is represented in the chart above, the built-up area has been increasing, hence threatening other land use and/cover types in City of Kigali’s wetland. Nowadays, wetland resources are threatened by being drained and fragmented with consequences of diversions of water supplies, and construction of infrastructures such as residential houses in the wetlands. This study found that the most observed changes which have had frequent impacts on Kigali’s wetland include: new infrastructure development such as roads, residential and commercial buildings. Consequently, the wetlands have been experiencing fragmentation, decrease of wetland surfaces, a decline of wetland productivity, particularly in terms of agricultural production

3.2 Effects of urbanization to the wetlands in the City of Kigali.

The total area of wetlands in Rwanda is approximately 278,000 ha of which, in 2009, 53% was used for cultivation. This accounts for 12% of the total cultivated land in the country (REMA, 2009).

Urbanization impacts wetlands in numerous direct and indirect ways. For example, construction reportedly impacts wetlands by causing direct habitat loss, suspended solids additions, hydrologic changes, and altered water quality (Darnell 1976). Indirect impacts, including changes in hydrology, eutrophication, and sedimentation, can alter wetlands more than direct impacts, such as drainage and filling (Keddy 1983). Urbanization may affect wetlands on the landscape level, through loss of extensive areas, at the wetland complex level, through drainage.

This study revealed that rapid urban growth has caused critical impacts on Rwampara wetland resources, especially on water and land resources. The mentioned impacts are associated with soil loss, land degradation, land fragmentation, decrease in water quantity and availability, decrease of agricultural productivity, and a critical shortage of water within the city. The main impacts associated with urban growth dynamics wetland resources in Kigali as identified in this study are, first and foremost, the change of land use from the wetland to other development

activities, especially the construction of residential and commercial buildings as well as road infrastructure. In addition, other impacts include increased flash floods risks as well as decreased water supply in the city. The following are impacts of urbanization on wetlands in the City of Kigali.

Some wetlands in Kigali areas have been converted for agricultural purposes, including rice farming and vegetable cultivation. The use of pesticides, fertilizers, and intensive land management practices in these areas can result in the contamination of wetland ecosystems and the loss of natural biodiversity.

Wetlands have been exploited for their natural resources, such as sand, clay, and peat. Unregulated extraction practices can damage wetland habitats, disrupt ecological processes, and diminish their ability to provide important ecological functions.

Gikondo industrial park led to the disruption of different fauna which failed to adapt to the changing micro-climate those industries brought in their natural habitats.

Some wetlands in the city of Kigali have become illegal dumping sites of solid materials because of the absence of a clear methodology of solid waste management especially in overcrowded areas.

Habitat Loss: As urban areas expand, wetlands are often drained or filled to create space for infrastructure development and human settlements. This leads to a significant loss of wetland habitats, which are crucial for many plant

and animal species.

Water Quality Degradation: Urbanization results in increased runoff from paved surfaces, leading to the accumulation of pollutants such as sediment, heavy metals, and chemicals in wetland ecosystems. These pollutants can degrade water quality and harm the flora and fauna that depend on the wetlands.

Disruption of Hydrological Processes: Wetlands play a vital role in regulating water flow, acting as natural sponges that absorb excess rainfall and release it slowly. Urbanization disrupts these hydrological processes by altering the natural drainage patterns, often leading to increased flooding events and reduced water availability during dry seasons.

Biodiversity Decline: Wetlands are home to a diverse range of plant and animal species, including migratory birds, amphibians, and aquatic plants. Urbanization fragments and isolates wetland habitats, leading to a loss of connectivity between different wetland areas. This fragmentation can disrupt ecological processes and result in the decline or loss of biodiversity.

To mitigate these negative effects, it is essential to implement sustainable urban planning and management practices. This may include preserving and restoring existing wetlands, implementing stormwater management strategies to reduce runoff and pollution, and promoting the use of green infrastructure within.

Reduced Ecosystem Services: Wetlands provide various ecosystem services, including water purification, flood

control, and carbon storage. Urbanization can diminish these services as wetlands are converted to urban infrastructure, resulting in decreased water quality, increased flood risks, and reduced capacity to sequester carbon.

Social and Cultural Impact: Wetlands hold cultural and recreational value for communities, providing spaces for leisure activities, education, and traditional practices. Urbanization can lead to the displacement of communities that rely on wetlands for their livelihoods, disrupting cultural traditions and social cohesion urban areas to mimic natural hydrological processes. Additionally, public awareness campaigns and community engagement can help foster a sense of stewardship towards wetland ecosystems and their conservation.

3.2. The possible solutions to offset the effects of urbanization to the wetlands in Kigali.

To offset the effects of urbanization on the wetlands in Kigali and ensure their long-term conservation, several solutions can be considered. Here are some possible approaches:

Sustainable Urban Planning: Implement comprehensive urban planning strategies that prioritize the protection and integration of wetlands into the city's development plans. This includes setting aside designated green spaces and buffer zones around wetlands to minimize encroachment.

Strict Regulatory Measures: Enforce regulations and zoning laws that restrict construction and land-use activities near wetland areas. This

helps prevent unauthorized encroachment and ensures that wetland ecosystems are not compromised by urban expansion.

Public Awareness and Education: Raising Awareness of the Population about Sustainable Use of Wetland Resources: This study has established that wetlands provide vital ecosystem services. However, it has been found that their socioeconomic and environmental values are not well recognized by local communities. Urban growth is gradually rapidly increasing while wetlands continue to face degradation and loss over time. The findings of the present study have also revealed that the main factor responsible for this is the over-exploitation of the wetland ecosystem.

Wetland Restoration and Rehabilitation: Identify degraded or impacted wetland areas and initiate restoration projects to restore their ecological functions. This may involve removing invasive species, reintroducing native vegetation, and improving water quality through appropriate measures.

Sustainable Stormwater Management: Develop and implement sustainable stormwater management practices, such as green infrastructure, and permeable surfaces. These measures help reduce the amount of runoff reaching the wetlands, minimizing the risk of pollution and flooding. Due to the

fact that most of the households in the Kigali do not have proper water-harvesting mechanisms and storm water management strategies. Consequently, domestic waters end up being drained into wetlands. Therefore, the present study suggests that water-harvesting mechanisms should be put in place to help the mitigation of flood risks. This would also contribute to the prudent use of the wetland's water resources. In addition, this study recommends that the informal settlements should be upgraded.

Collaboration and Stakeholder Engagement: Foster collaboration among government agencies, local communities, environmental organizations, and other stakeholders to collectively address wetland conservation challenges. This can involve partnerships for monitoring, research, and joint conservation initiatives. This study suggests that local communities should be involved at every phase of planning and implementing programmes related to wetland management. The interviewed natives in Kigali's wetland revealed that if fully involved, they would participate in activities related to the sustainable management of the wetland and would become stewards of the wetland ecosystem. Lastly, if they are fully involved, they would strive to maintain the ecological balance of the wetland ecosystem by managing its resources wisely.

Economic Incentives: Explore the possibility of providing economic incentives, such as tax breaks or subsidies, to individuals or businesses that contribute to wetland conservation efforts. This can encourage private landowners and developers to adopt practices that protect wetland areas.

Long-term Monitoring and Management: Establish robust monitoring programs to regularly assess the health and functioning of wetlands in Kigali. This data can inform adaptive management strategies and guide future conservation actions.

4.3. The policy and legislation framework for managing urban wetlands in the city of Kigali.

In Rwanda, many laws, policies and regulations have been established with regard to wetland protection and natural resources management. These include the law governing biodiversity in Rwanda, the organic law determining the modalities of protection, conservation and promotion of environment policies in Rwanda, Rwanda Biodiversity Policy, and many others. The efforts that are being made by the Rwandan government and environmental organizations to address these issues and promote wetland conservation. Initiatives include the establishment of protected areas, wetland restoration projects, and raising awareness about the importance of wetland ecosystems for sustainable development, Proposal to Minimum green Building compliance.

Therefore, it is suggested that existing policies should be strictly implemented before looking for alternative solutions for

sustainable urban wetland management and those include the Prime minister's order no 006/03 of 30/01/2017 drawing up a list of swamp lands, their characteristics and boundaries and determining modalities of their use, development and management, Kigali city master plan 2020-2050, Promoting urban Eco-tourism. (Nyandungu Eco-tourism.) relocation of Industries to Economic zones/Masoro, law N°48/2018 Of 13/08/2018 on Environment, National Wetlands Management Framework for Rwanda, 2020 as well as Law N° 27/2021 of 10/06/2021 Governing Land.

4. Conclusion

Over the past 23 years, many changes have happened in Kigali City. These changes have caused serious negative impacts on wetland resources. For the case of urban wetland especially in Kigali, the study has identified these negative effects to include but not limited to biodiversity decline, reduce ecosystem services, disruption of hydrological processes including decrease of water supply from wetland to the city, and land use changes from wetland nature to other development activities such as roads, residential and commercial buildings. In solving this problem, there is a need to sustainably manage wetland in the city of Kigali.

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