

The Impact of Gatsata Sub-Catchment Land Use Changes on Nyabugogo Wetland, Rwanda

JULIEN NSANZIMANA*, AND NDIKUBWIMANA INNOCENT

Department of Spatial Planning, School of Architecture and Built Environment, College of Science and Technology, University of Rwanda, KN 67 Street Nyarugenge, Kigali, Rwanda

Abstract

The world is witnessing rapid population growth, leading to substantial rural-to-urban migration and subsequent high levels of urbanization. Urban development, however, often results in the loss of wetlands, with some areas experiencing more than a 60% reduction. Urbanization, especially in developing countries like Rwanda, poses significant threats to wetland ecosystems due to activities such as construction, mining, and quarrying. This study focuses on Gatsata Sub-catchment in the City of Kigali, Rwanda, where urbanization and population growth have led to drastic land use and land cover changes over the past 23 years. The Nyabugogo wetland in Gatsata sub-catchment is facing not only habitat loss and hydrological changes but also frequent and destructive urban flash floods. The research aims to assess the impact of land use and land cover changes on Nyabugogo wetland in Gatsata Sub-catchment. This study involves a comprehensive approach, utilizing online research, spatial data analysis, and satellite imagery to investigate land use changes from 2000 to 2023. Factors influencing the management of Gatsata Sub-catchment, including topography, infrastructure, and human activities, are explored. The study identifies critical impacts on Nyabugogo wetland, such as habitat loss, water quality degradation, disruption of hydrological processes, biodiversity decline, and social-cultural impacts. Mitigation strategies are proposed to offset the negative impact, including sustainable urban planning, strict regulatory measures, public awareness and education, wetland restoration, sustainable infrastructure development, and collaboration among stakeholders. Economic incentives and long-term monitoring are also suggested to encourage conservation efforts and ensure the health and functioning of wetlands.

Keywords: Wetland, Sub-Catchment, Land use and Land Cover, Nyabugogo Wetland

INTRODUCTION

The global population is undergoing constant and rapid growth, with a predominant trend of migration from rural to urban areas, resulting in a significant increase in urbanization (Andreea, 2020). Barman (2021) has noted that urban development contributes to the loss of wetlands, surpassing 60%. Wetlands, characterized as transitional zones

between aquatic and terrestrial ecosystems, remain inundated or saturated with water for a sufficiently long period to generate hydric soil and sustain hydrophytic vegetation (Chen et al., 2010).

Across the globe, the primary driver of disruptions in urban wetlands is urbanization. This process influences urban wetlands either directly or indirectly by transforming their natural environment into alternative economic activities such as construction, mining, and housing. The alteration of wetland characteristics leads to immediate habitat loss, the introduction of suspended solids, alterations in hydrology, degradation of water quality, heightened runoff volumes, reduced

**Correspondence Author:* Julien Nsanzimana, Department of Spatial Planning, School of Architecture and Built Environment, College of Science and Technology, University of Rwanda, KN 67 Street Nyarugenge, Kigali, Rwanda; E-mail: juliennsanzimana@gmail.com

infiltration, and other associated impacts (Ajibola et al., 2012).

Rwanda is presently facing notable strain on its agricultural land, a consequence of swift population growth and limited availability of fertile land. The density of the rural population has escalated from 121 individuals per square kilometer in the 1960s to 262 in 1990, and it has continued to rise, reaching 380 persons per square kilometer in 2010, covering an expanse of 523.03 square kilometers (NSR, 2022). Currently, the Rwandan government recognizes the significance of wetlands in bolstering food security and income through the cultivation of rice and other crops (REMA, 2009). Rwanda possesses a total wetland area of 278,536 hectares. Nevertheless, as of 2010, only 5,000 hectares out of the 148,344 hectares designated for cultivation have been officially reclaimed, often with insufficient attention to design and maintenance (Nabahungu and Visser, 2011b).

The land use and land cover in the Gatsata sub-catchment have undergone significant transformations over the past 23 years (from 2000 to 2023), primarily driven by the increasing population in the City of Kigali. The population surge in urban areas has exerted pressure on urban ecosystems, contributing to the degradation of wetlands (Stella, 2010). Similar to many other developing nations, Rwanda has witnessed rapid urbanization in recent years, with the City of Kigali serving as the epicenter of this urban growth. This expansion has resulted in substantial alterations in land use and infrastructure development, prompting concerns about the potential impact on the country's wetland ecosystems.

The process of urbanization stands out as a significant contributor to the continuous rise in flood hazard events and associated losses globally. This is primarily attributed to the escalating presence of impervious surfaces and the heightened vulnerability of people and their assets. The expansion of urban impervious surfaces, including houses and roads, diminishes the former rural catchment's infiltration capacity. Consequently, there is an increase in water flow available for runoff, leading to flash floods (Ntaganira et al., 2020). Kigali City is grappling with a growing challenge of urban flooding. Over the past few years, significant flood events have resulted in damage to infrastructure, landslides, soil erosion, environmental degradation, as well as injuries and fatalities (Nabahungu and Visser, 2011; NISR, 2022). This situation is exacerbated by the unchecked urban growth, occupation of floodplains, and inadequate drainage systems that characterize the city.

As a result, the swift expansion of urbanization and population growth is giving rise to substantial challenges for wetland resources in both rural and urban environments. The impact is especially evident in urban areas, with the City of Kigali experiencing more pronounced consequences than other locations. The primary factors contributing to these adverse effects on wetland resources in Kigali City encompass development activities like industries, human settlements, trade and transport infrastructure, and urban agriculture. Currently, only 24% of Kigali City's original wetlands remain unaffected. Notably, the Nyabugogo wetland, along with others in the city, confronts these threats and experiences drainage into the river Nyabugogo, a vital water source for the city.

(Rwanyiziri G et al., 2020). Moreover, the Nyabugogo wetland is increasingly susceptible to frequent and destructive urban flash floods in Kigali City (Perez-Molina et al., 2016). This study aims to evaluate the impact of alterations in land use and land cover in the Gatsata Sub-catchment on the Nyabugogo wetland.

MATERIALS AND METHODS

Description and Delimitation of Study Area

Gatsata sub-catchment is located in the City of Kigali (CoK), Gasabo District, the catchment discharges into three sectors: Gatsata, Gisozi and Jali sectors. The climate in this catchment is predominantly of temperate and equatorial types, featuring an average temperature ranging from 16°C to 23°C, depending on the altitude of the area. The annual rainfall in the catchment varies between 800 mm and 1,600 mm (Ntaganira et al., 2020).

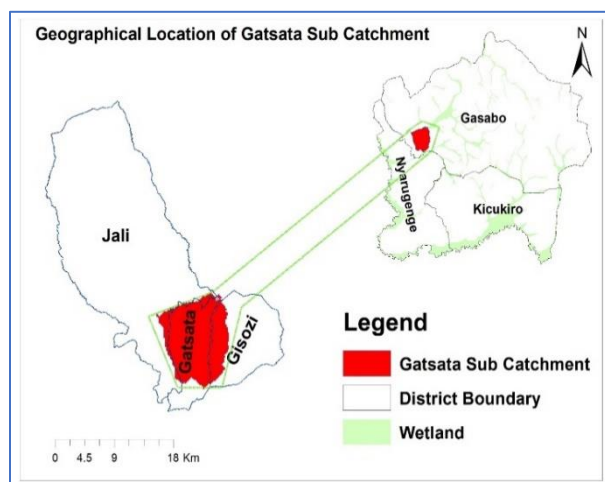


Figure 1. Geographical location of Gatsata sub-catchment

Data Collection Methods

Data collection involves systematically gathering and measuring information on variables of interest to address specific research questions and assess outcomes. The overarching objective in all data collection endeavors is to capture high-quality evidence that effectively addresses posed questions. This stage holds significant importance in the research process; even with the most exemplary research design, the inability to collect the necessary data can impede the successful completion of a project (Muhammad & Kabir, 2018). This section summarizes secondary data collection that has been used in the Assessment on the impact of Gatsata Sub-catchment land use land cover change on Nyabugogo wetland.

Secondary Data Collection

According to Victor, Secondary data refers to information that has already been gathered from primary sources and is made readily accessible for researchers to utilize in their own investigations. It comprises data collected by someone else previously, which is then made available for use by another researcher. Furthermore, the secondary data collection sources are government publications, websites, books, journal articles and internal reports (Vector, 2017). In this research, we used online research and spatial data analysis to review and analyze data for Assessing the impact of Gatsata Sub-catchment management on Nyabugogo wetland.

Online research serves as a direct and accessible introduction to social research conducted on the internet (Tristraham at al,

2011). This study involved the utilization of various online resources, such as published articles, websites, online books, and journals.

According to Xiaoyi and Tao (2012), spatial data analysis is a collection of techniques aimed at describing and visualizing spatial distributions. It involves discovering patterns of spatial association, identifying atypical observations, and suggesting various spatial regimes or other forms of spatial heterogeneity (Xiaoyi & Tao, 2012). Geographic information systems are recognized for executing fundamental tasks in spatial data analysis, encompassing functions such as capture, input, storage, analysis, and output (Chatterjee, 2010). Geographical Information System (GIS) and Erdas Imagine 2014 softwares were used to classify series Landsat images in order to determine the land Use Land Cover changes from 2000 to 2023 and preparing thematic maps of Gatsata Sub-catchment area.

RESULTS AND DISCUSSION

Factors Influencing the Management of Gatsata Sub-Catchement to Nyabugogo Wetland

Land Use Land Cover Change from 2000-2023

Owing to numerous activities and its strategic location, Nyabugogo and the surrounding areas have become magnets for a considerable influx of people, resulting in the emergence of slums in the vicinity, including the Gatsata sub-catchment. Over the past 23 years, this influx has contributed to the modification and degradation of Nyabugogo wetland. Similar to other land use changes in the Gatsata sub-catchment, these alterations

have exacerbated the issue of flooding, which has become increasingly prevalent in the swamps and wetlands of the Nyabugogo area in recent times.

The built-up area has experienced a significant and rapid expansion, and the constructed buildings lack adequate water harvesting mechanisms. The trenches and canals established in the sub-catchment by urban authorities have limited capacity to effectively harvest rainwater and regulate water flow without posing environmental risks to the Nyabugogo wetland (Kayijuka & Nzayinambaho, 2020). The land use and land cover (LULC) in the sub-catchment have been classified into four categories, which include water bodies, agriculture (cropland), wetland, and forest zones.

Within the catchment, the expansion of the built-up area poses a threat to various land use and cover types in and around the Nyabugogo wetland. The gradual changes in land use and land cover (LULC) have not only significantly impacted Nyabugogo wetland but also influenced broader land use trends and cover types. These effects exhibit both positive aspects, such as economic growth from natural resource exploitation, and negative aspects, including biodiversity loss, reduction in agricultural and forest lands, among others (Gasipari G, 2020). The argument for LULC change suggests that rapid urban growth has resulted in the gradual depletion of resources, leading to soil loss, land degradation, land fragmentation, decreased water quantity and availability, reduced agricultural productivity, and a critical water shortage within the city.

Topographical Condition

Nyabugogo wetland has encountered recurrent flooding, primarily attributed to its

lower topography, serving as a convergence point for the drainage systems of Kigali city.

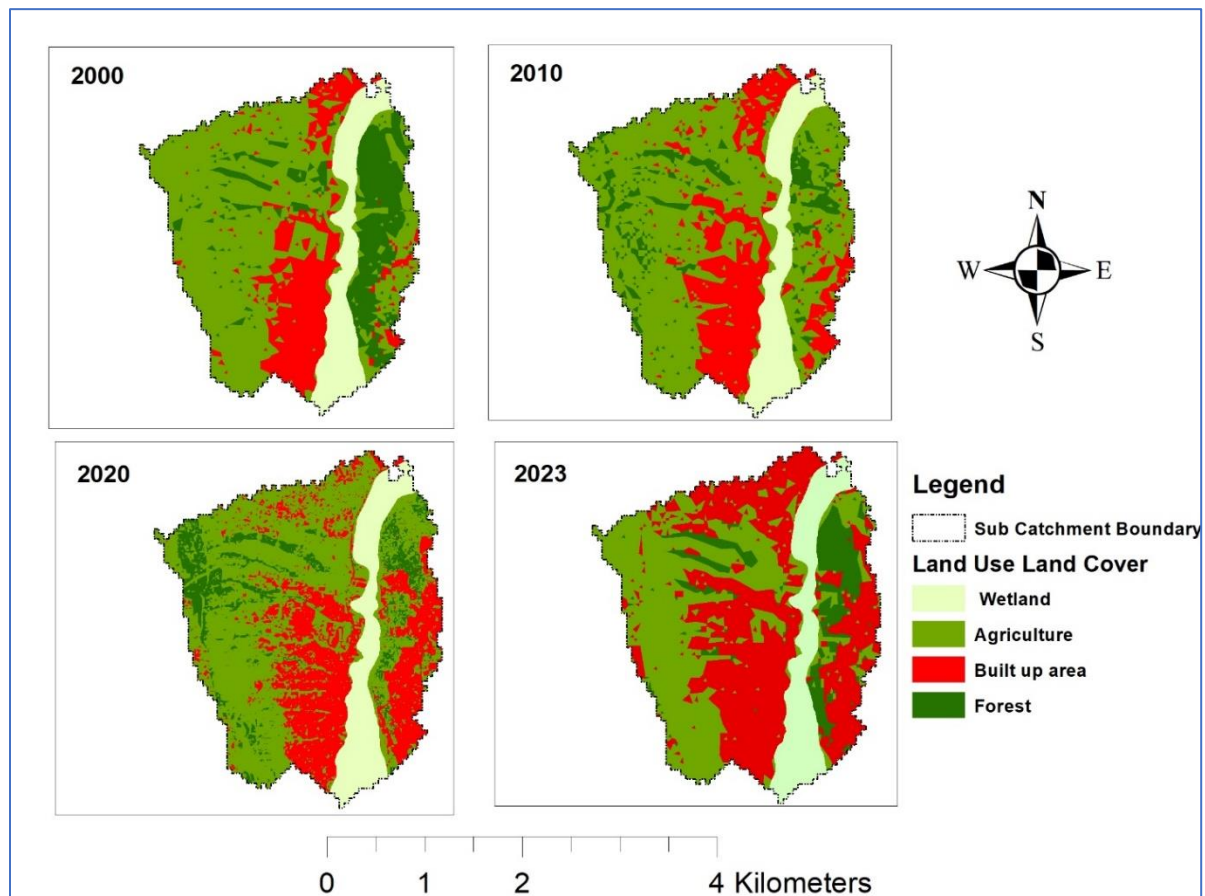


Figure 2. Land Use Land Cover changes in Gatsata sub-catchment in last 23 years

The heightened precipitation linked to climate change, coupled with urban development in the Nyabugogo floodplain,

amplifies the risk and damages associated with floods in the wetland (REMA, 2015).

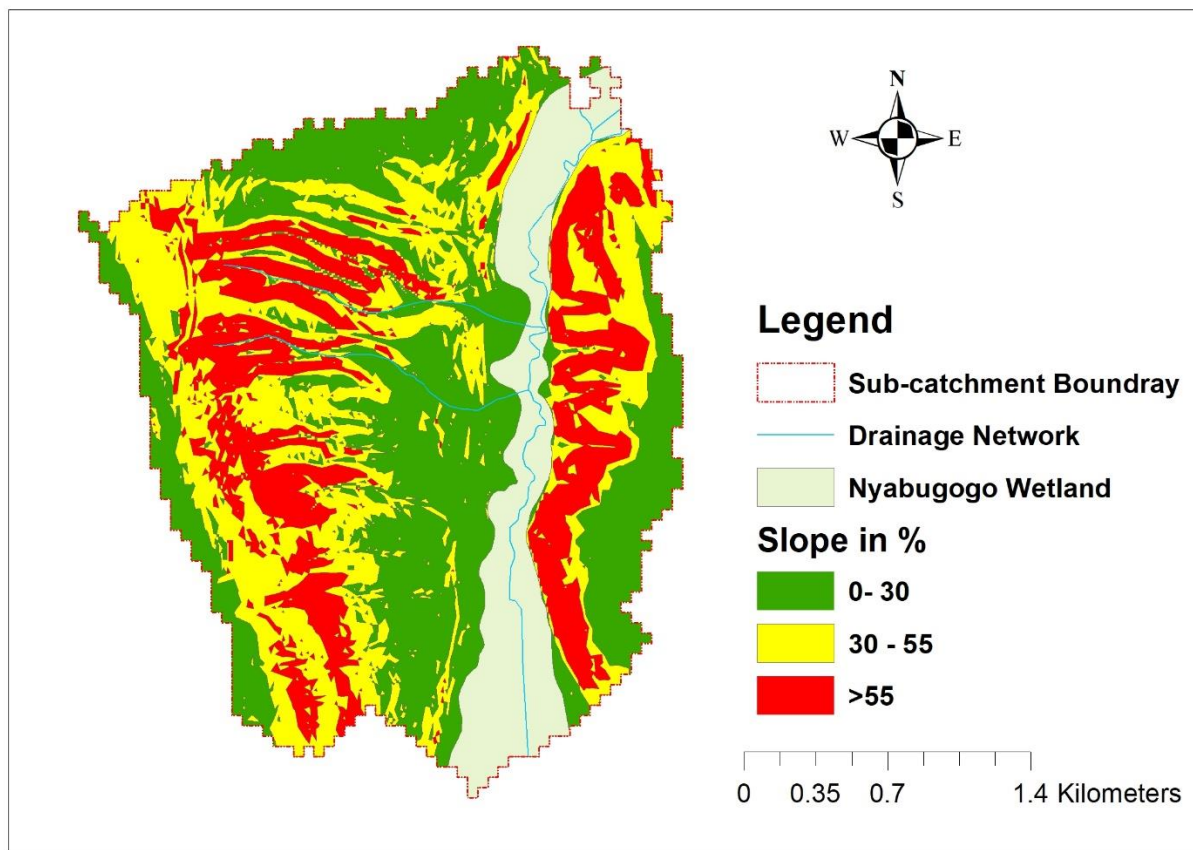


Figure 3. Topographical nature of Gatsata sub-catchment

The Gatsata Sub-catchment is among the most urban areas within informal settlement built on the steep slope in the City of Kigali. Its physical criteria resulting floods to Nyabugogo wetland due to high-level built-up areas, lack of proper storm water management plan on the infrastructures. The figure above indicates that both side of Gatsata and Gisozi is associated with steep slope above 55% as well as gentle slope between 30%-55% which speed up water runoff to the Nyabugogo wetland.

Infrastructure and storm water management

Wetlands play a crucial role as the primary source of provisioning services, supporting

subsistence and commercial crops, as well as providing livestock feed and fresh water. The absence of protective measures for the surrounding mountains from runoff, along with inadequate drainage systems, has been identified as significant contributors to flooding in Nyabugogo wetland (Ntaganira et al., 2020). Given its extensive river network and large wetlands, Rwanda is frequently threatened by riverine floods. Particularly in Kigali City, heavy rainfall events result in swift surges in river flows and drainage systems, leading to downstream floods.

The observed issue primarily stems from the absence of effective stormwater management strategies and insufficient infrastructure to handle the peak runoff accumulation from upstream areas like Gatsata, Kimisagara, Muhima and Gisozi. Additionally, this study indicates a rising trend in flood risks, attributed to the development of new infrastructures and buildings, particularly informal settlements or

slums. In these areas, domestic water control is lacking due to limited water harvesting systems and inadequate water channels. Notably, the Nyabugogo natural wetland in Kigali City, Rwanda, receives various untreated wastewaters, including those from industrial areas (Nkuranga et al., 2010).

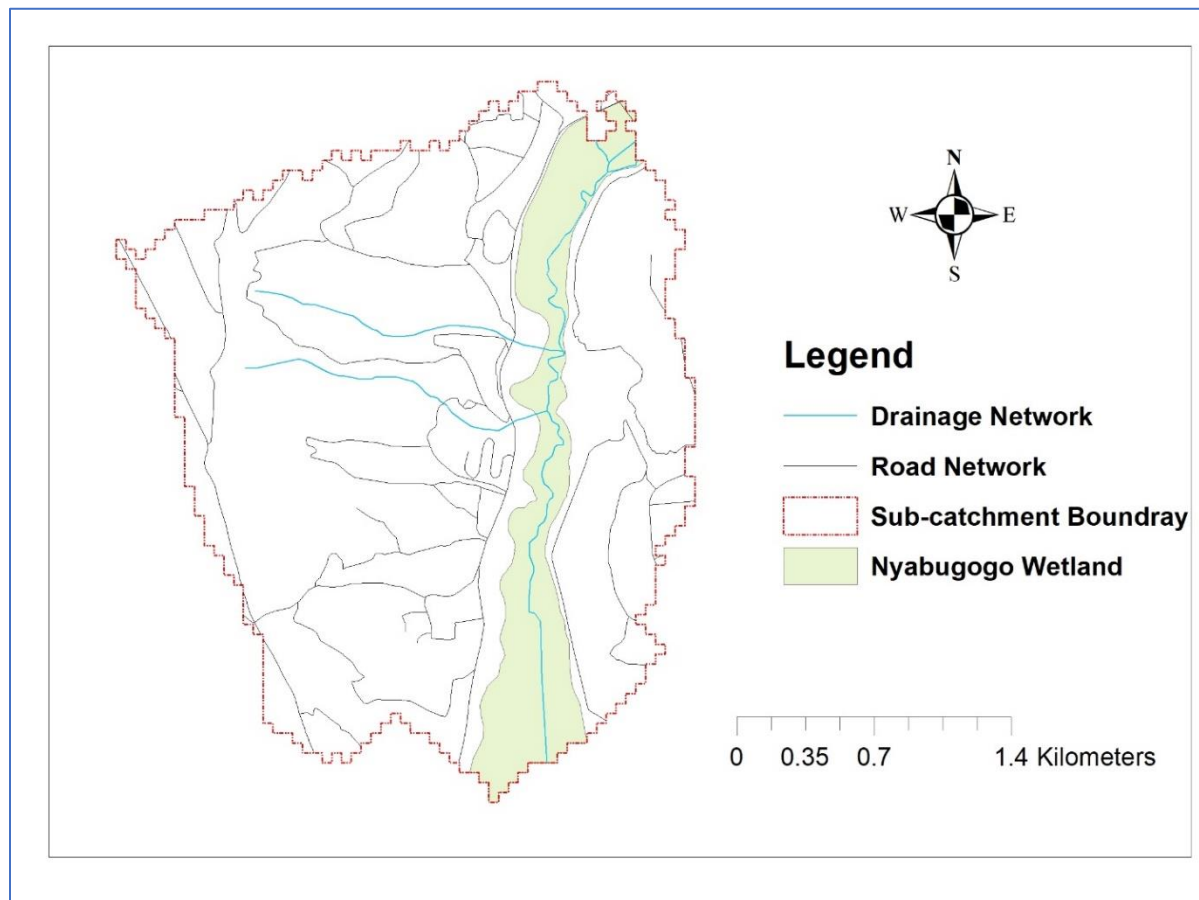


Figure 4. Distribution of infrastructure and drainage network in Gatsata sub-catchment.

The sewerage system and waste disposal practices in the Gatsata sub-catchment do not adhere to standard guidelines, resulting in an unfriendly environment. Some waste is improperly dumped in the swamp, posing a

threat to the lives of residents and individuals conducting activities in the Nyabugogo area (Kayijuka & Nzayinambaho, 2020).

Human Activities

The local wetlands in Kigali have exerted a notable impact by human activities. These wetlands play a pivotal role in upholding ecological balance, providing essential habitats for a diverse range of plant and animal species, and furnishing various ecosystem services. However, the conversion of natural wetlands into agricultural farms has far-reaching effects, elevating nutrient and residue concentrations in water bodies (Musabyimana and Bazimenyera, 2023). Several wetlands in Kigali have undergone transformation for agricultural purposes, including rice farming and vegetable cultivation. The application of pesticides, fertilizers, and intensive land management practices in these areas can lead to the contamination of wetland ecosystems and the depletion of natural biodiversity.

Impact of Gatsata Sub-Catchment Land Use Land Cover Changes on Nyabugogo Wetland

Urbanization exerts a multitude of direct and indirect impacts on wetlands. Construction activities contribute to direct habitat loss, the addition of suspended solids, hydrologic alterations, and changes in water quality Darnell (1976). In contrast, indirect impacts, such as alterations in hydrology, eutrophication, and sedimentation, can potentially have a more significant effect on wetlands compared to direct impacts like drainage and filling, as suggested by Keddy (1983). The influence of urbanization extends to wetlands at both the landscape level, leading to the loss of extensive areas, and at the wetland complex level, primarily through drainage.

This study revealed land use land cover changes in the sub-catchment has caused critical impacts on Nyabugogo wetland, especially on water, ecosystem, biodiversity and land resources. The following are impacts of land use land cover changes on Nyabugogo wetlands in Gatsata sub-catchment.

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.

Degradation of water quality: The process of urbanization contributes to heightened runoff from paved surfaces, causing the buildup of pollutants like sediment, heavy metals, and chemicals within wetland ecosystems. This accumulation of pollutants has the potential to degrade water quality, posing a threat to the flora and fauna dependent on the wetlands (McInnes, 2010).

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 flash flooding events and reduced water availability during dry seasons (Arrighi et al., 2017).

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.

Social and cultural impact: Wetlands carry cultural and recreational importance for communities, serving as spaces for leisure activities, education, and traditional practices. The process of urbanization may result in the displacement of communities that depend on wetlands for their livelihoods, disrupting cultural traditions and social cohesion. To mitigate these effects, urban planning should aim to mimic natural hydrological processes and promote the integration of wetlands into urban areas. Furthermore, fostering a sense of stewardship towards wetland ecosystems and their conservation can be achieved through public awareness campaigns and active community engagement.

Possible Solutions to Offset the Impact of Gatsata Sub-Catchment Land Use Changes on Nyabugogo Wetland

Possible solutions to offset the impact of Gatsata sub-catchment land use land cover changes on Nyabugogo wetland are described below.

Sustainable urban planning and management practices: Implement comprehensive urban planning strategies that prioritize the protection and integration of Nyabugogo wetlands into the city's development plans. This includes setting aside designated green spaces and buffer zones around wetlands to minimize encroachment as well as upgrading informal settlement around Nyabugogo Wetland.

Strict regulatory measures: In Rwanda, many laws, policies and regulations have been established with regard to wetland protection and natural resources management including 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: 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: This is through identifying 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 infrastructures: To mitigate the impacts of rapid urbanization the Nyabugogo wetland sustainable infrastructures should be established including roads with drainage channels, upgrading natural drainage as well as proposing hydraulic structure in Gatsata sub-catchment to reduce the magnitude of the effect of flood in the area (Munyaneza and Nzeyimana, 2013).

Sustainable Stormwater Management: These measures help reduce the amount of runoff reaching the wetlands, minimizing the risk of pollution and flooding. Fact showed that most of the households in the Gatsata sub-catchment 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.

Collaboration and stakeholder engagement: Collaboration among government agencies, local communities, environmental organizations, and other stakeholders fosters collectively address Nyabugogo 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 Nyabugogo 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 Nyabugogo 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: Establishing robust monitoring programs to regularly assess the health and functioning of wetlands in Kigali can inform adaptive management strategies and guide future conservation actions.

CONCLUSION

Over the past 23 years, many changes have happened in Gatsata sub catchment. These changes have caused serious negative impacts on Nyabugogo wetland. For the case of Nyabugogo wetland, the present study has identified these negative effects to include but not limited to risks of Biodiversity Decline, Disruption of Hydrological Processes, Social and Cultural Impact, 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 establish effective strategies towards better sustainable management of Nyabugogo wetland including Economic Incentives, Collaboration and Stakeholder Engagement, Sustainable Stormwater Management, Sustainable infrastructures, Strict Regulatory Measures, Public Awareness and Education and Sustainable Urban Planning and Management practices.

REFERENCES

- Ajayi, Oluwatosin victor. 2017. Advanced statistical methods in education. P1-5.
- Ajibola, M. O., Awodiran, O. O., & Salu-Kosoko, O. 2013. Effects of infrastructure on property values in unity estate, Lagos, Nigeria. *International Journal of Economy, Management and Social Sciences*, 2(5), 195-201.
- Arrighi, C., Tarini, F., Vicario, E., Castelli, F. 2017. Flood impacts on a water distribution network.
- Chatterjee, S., Shah, P.K., Dubey, J. S. 2010. Transactions of the Indian institute of metals: Computation of diametral deformation of irradiated Zr-2.5 Nb

- pressure tubes from RAPS-2, V 63, p 369-372.
- Chen, H., Wang, G. and Lu X. 2010. Wetland science: Wetland Definition Creation, Evolution and Application. Vol 8 No.3 Sept 2010.
- Helen, B. 2019. Combating land degradation and desertification: the land use planning quandary. 81100 Lesvos, Greece.
- Kayijuka & Nzayinambaho. 2020. Assessment of Urbanization Effects on Environmental Security. Case of Nyarugenge District. *East African Journal of Science and Technology*, **11**: 1.
- Keddy, P.A. 1983. Freshwater wetlands human-induced changes: indirect effects must also be considered. *Environmental Management* 7(4): 299-302.
- Ma, X., Pei, T. 2012. Exploratory analysis of regional economic disparities in Beijing during 2001-2007. DOI: 10.1007/978-3-642-25926-5_4
- McInnes, R. 2010. Urban and peri-urban wetlands: Background and update on progress, (December). Ramsar Workshop of the STRP NFPs in Africa, Johannesburg, 30th November – 2nd December 2010
- Muhammad, S., & Kabir, S. 2018. Basic Guidelines for Research an Introductory Approach for all. Basic Guidelines for Research: An Introductory Approach for All Disciplines, August 557.
- Musabyimana, J.P. and de Dieu Bazimenyera, J. 2023. Assessment of the Impacts of Converting Natural Wetlands to Agricultural Farms. Case of Nyabugogo, Kigali City, Rwanda. *Agricultural Sciences*, 14:422-431.
<https://doi.org/10.4236/as.2023.143027>
- Nabahungu, NL., Visser, SM. 2011. Contribution of Wetland Agriculture to Farmers' Livelihood in Rwanda. *Ecol. Econ.* 71: 4 – 12
- NISR, (2022). The fifth Rwanda Population and Housing Census (RPHC5). Government of Rwanda, Kigali. *Nat. Hazards Earth Syst. Sci.* 17: 2109 - 2123.
- Nkuranga et al. 2010. Water Air Soil Pollut: Fate of Heavy Metals in an Urban Natural Wetland:The Nyabugogo Swamp (Rwanda). DOI 10.1007/s11270-010-0426
- Ntaganira et al. 2020. International Journal of Environmental Planning and Management. Vol. 6, No. 2, 2020, pp. 40-46). Impact of Flood on Wetland Ecosystem Services in Rwanda. ISSN: 2381-7240 (Print); ISSN: 2381-7259 (Online)
<http://www.aiscience.org/journal/ijepm> .
- Perez-Molina, E., Sliuzas, RV., Van Maarseveen, MFAM., Jetten, VG. 2016. Urban Flood Management under Rapid Growth in Kigali, Rwanda: Developing Perspectives on Land Use Planning and the Future by Exploring the Case of the Rwampara Wetland. In: H. D. Schmitt H. D.
- REMA. 2015. Rwanda State of Environment and Outlook Report 2015. Kigali: Rwanda Environment Management Authority
- Rwanyiziri et al. 2020. Spatio-temporal Analysis of Urban Growth and Its Effects on Wetlands in Rwanda. The Case of Rwampara Wetland in the City of Kigali. *J. Appl. Sci. Environ. Manage*, 24: 1495-1501.
- Tao, T., Tan, Z., and He, X. 2007. Integrating environmental into land use planning through strategic environmental assessment in China: Towards legal Frameworks and operational procedures. *EIA Review*, **27**; 243-265.
- Tristram, H, Jane. W, John, M 2011. What is online Research? Using the Internet for Social Science Research. Bloomsbury USA: ISBN: 978-184966-524-7.
- Wali, UG. 2013. Nile Basin Water Science & Engineering Journal, Volume- 6. Hydraulic Structures Design for Flood Control in the Nyabugogo Wetland, Rwanda.