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SPATIO-TEMPORAL ANALYSIS OF THE EFFECTS OF LAND USE CHANGE ON WETLANDS DEGRADATION IN RWANDA FROM 2000 TO 2020. THE CASE OF BAHIMBA WETLAND IN RULINDO DISTRICT

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Abstract: ***The study entitled 'Spatio-temporal Analysis of the Effects of Land Use Change on Wetland Degradation in Rwanda: A Case Study of Bahimba Wetland in Rulindo District' aimed to achieve four specific objectives, such as to assess the dynamics of land use change in the area of Bahimba Wetland from 2000 to 2020; to investigate the major drivers of land use change in the vicinity of Bahimba Wetland and their impact on natural resources, particularly forested land; and to evaluate the level of degradation in Bahimba Wetland resulting from land use changes during the same period. The study employed a survey-based, descriptive, qualitative, and quantitative design, utilizing both primary and secondary data. Data collection methods included questionnaires, field interviews, and documentation. Data analysis involved tools such as SPSS (Statistical Package for Social Scientists) for quantitative data and GIS (Geographic Information System) tools along with Google Earth for geospatial data and for qualitative data, the study has summarized all ideas and reported in chapter four. The findings emphasized the critical role of wetlands as ecosystems that offer various benefits at local and global levels, including water quality enhancement, biodiversity support, and recreational opportunities. However, human-induced activities, particularly land use changes, often lead to wetland degradation. Understanding these impacts is crucial for informed decision-making. The study highlighted the negative consequences of losing ecosystem services value due to land use and land cover changes, affecting local climate, waste management, and community livelihoods. The study findings reveal that the model exhibited an F ratio of 10.184, with a P value less than 0.05. This indicates that the F ratio is statistically significant. Consequently, the overall regression model, encompassing all tested variables, also demonstrates statistical significance and can be employed for prediction at a 1% significance level. Furthermore, the predictor variables specifically, Land for agriculture (X1), Land Forest (X2), and Land for Builtup and bare soil (X3) are statistically significant in relation to wetland degradation (Y). These land use changes, including shifts in agriculture, forest, and built-up areas, significantly impact water pollution, soil quality, biodiversity, ecosystems, indigenous plants, and climate change. Notably, there exists a low level of awareness regarding land use policies, agricultural policies, environmental management, and natural resources management. Consequently, uncontrolled economic activities, such as constructing houses in Bahimba wetland, underscore the need for increased awareness and robust measures like wetland restoration to safeguard biodiversity, water quality, and ecosystem health. To mitigate this, interventions should prioritize wetland restoration and sustainable management, both in urban and rural contexts. Ultimately, achieving a balance between development and environmental conservation is essential, especially in wetland ecosystems. By understanding the consequences of land use changes, we can make informed decisions to protect these valuable natural resources.***

Keywords: Spatio-temporal analysis; Effects; Land Use Change; Climate change, Wetlands degradation; Bahimba wetland, Rwanda.

0. Introduction

Wetlands are defined as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing; fresh, brackish, or salty, including areas of marine water the depth of which at low tide does not exceed 6 m (Ramsar, 2016)

These areas can be natural or man-made, permanent or temporary, and may contain static or flowing water. Wetlands encompass a range of conditions, from freshwater to brackish or salty, and even include marine areas where the water depth at low tide does not exceed 6 meters. Due to their significant biological, ecological, social, cultural, and economic values, wetlands play a crucial role in the environment (Assefa, 2021). They are considered as biodiversity isles because they represent the transitional zone between terrestrial and aquatic habitat. Though occupying only 2% area of the world, wetlands contain 10 to 14% of the carbon storage (NISR, 2022) and support extensive food chains along with providing valuable habitats for variety of breeding, wintering and migratory species of wildlife. In this sense, these environments are imperative locales for preservation (Moskal, 2024). Nearly 50% of the world's wetlands have vanished within the final century due to horticulture and urban improvement (Ackland, 2022). Status of wetland depends on its administration, levels of anthropogenic exercises, administration of arrive, strong squander collection and transfer, transfer of utilized water and state of mind of the individuals at expansive (Dwindle, 2023).

Wetlands are among the foremost profitable and critical biological systems on the soil, however they have been subject to rehashed and emotional chronicled misfortunes, and until these days, they proceed to be at tall chance of debasement and add up to annihilation. it was evaluated that 50% of salt bogs and 35% of mangroves have been either misplaced or corrupted with the extent surpassing 90% in a few regions (Gibson et al., 2015).

In fact, the world has lost 64-71% of its wetlands during 20th and 21st centuries, and those losses have been larger and faster than other previous centuries (Kharel, 2010). The 19th century experienced an industrial revolution, the 20th a technological revolution, while the 21st is significantly challenged by an urban revolution where cities are rapidly growing and most of people strive to live in urban areas. This has caused an overexploitation of various natural resources among which wetlands are remarkable, in both urban and peri-urban areas (Hu et al., 2017).

In Africa, wetlands constitute almost 1 % of its add up to range, and they contribute essentially on the continent's biodiversity and populace employments. The most noteworthy concentration of wetlands happens generally between 15°N and 20°S. It incorporates 4 fundamental sorts to be specific wetlands of the four major riverine frameworks (Nile, Niger, Congo and Zambezi); Lake Chad and wetlands of the inward Niger Delta in Malu, the Crack Valley lakes such as Victoria, Tanganyika, Nyasa, Turkana, Mweru and Albert); the Sudd in Southern Soudan and Ethiopia and the Okavango Delta in Botswana (Metz, 2017). All of the wetlands show lavishness and uniqueness in biodiversity. All sorts of wetlands in Africa bolster an incredible differing qualities of plants and creatures, and their efficiency gives characteristic assets basic to the survival of critical portion of the African country populace (Gibson et al., 2015).

In East Africa region, wetlands cover about 18 million ha (about 7% of the region). However, a small portion is under effective management for food production, and this is primarily benefiting the region's development as well as human livelihoods (Junk et al., 2013 & Leemhuis et al., 2016). However, nowadays food production and other productivity from wetlands in East Africa are stagnating and even declining due to consequences of land and natural resources degradation. This is mainly caused by population pressure, as most of countries in the region (Rwanda, Kenya, Uganda, Tanzania and Burundi) are experiencing a rapid land use change.

For the case of Rwanda, the entire range of wetlands in Rwanda is roughly 278,000 ha of which, in 2009, 53% was utilized for cultivation and this accounts for 12% of the entire developed arrive within the nation (REMA, 2009). The decrease of the estimate of wetlands has driven to the debasement of their assets, particularly arrive and woodland. In reality, arrive utilize alter from forested arrive into arable arrive appeared a critical increment where over 880 and 1,150 km2 of timberland range changed over into developed arrive utilize in 1992 and 2014, individually (FAO, 2016). The main cause of this change in terms of land use patterns within the area of wetlands is mainly linked to the increase of population in the country with population densities estimated to 571 inhabitants/km2 (NISR, 2023). In addition, the dependence on agricultural activities by almost 80 % of Rwandan population constitutes another cause.

1. Statement of the problem

Rwanda stands among the African nations steadfastly pursuing the Sustainable Development Goals (SDGs) by 2030, with a particular focus on Goal 15. This goal aims to protect, restore, and advocate for the sustainable use of terrestrial ecosystems, while also managing forests sustainably, combating desertification, halting and reversing land degradation, and mitigating biodiversity loss. Specifically, Goals 15.2 and 15.5 target the promotion of sustainable forest management practices and the implementation of significant measures to mitigate habitat degradation by the year 2020 (UN, 2022).

In Rwandan rural areas many people are not aware about land use needs which could not affect wetland quality. Due to that, people change land use as they want vis a vis their economic needs and this results into wetland degradation. This is clear where some people have built houses in the area of wetland, other have developed hill crops in wetland, deforestation activities were increased and soil extraction activities, due to that wetland was affected and lead to climate change, water pollution, loss of soil quality and other degradation structures. This study intends to assess whether the same problem has taken place in Bahimba wetland and which measures could be taken to restore this wetland.

Therefore, this study aims at contributing to the analysis of effects of land use change on wetlands degradation in Rwanda. Specifically, the study will focus on the Bahimba wetland in the Rulindo district. This will help understand the major factors of land use change in the Rulindo district and their effects on the Bahimba wetland and other ecosystems. The study will analyze trends and dynamics of land use change over space and time from the 2000s to 2020.

2. Objectives of the study

This study aims to conduct spatio-temporal analysis of the effects of land use change on wetlands degradation in Rwanda the case of Bahimba wetland in Rulindo district. And specifically this study intends:

1. To assess the dynamics of land use change in the area of Bahimba wetland located in Rulindo district since 2000 up to 2020;

2. To investigate major drivers of land use change in the area of Bahimba wetland and their effect on its natural resources especially land forest;

3. To evaluate the level of Bahimba wetland degradation as an outcome of land use change since 2000 to 2020.

3. Literature review

Assefa (2021) ponder explores the worldly and spatial land-use/land-cover (LULC) alter designs over 35 a long time (1984 to 2019) in Bahir Dar City, Ethiopia. It assesses the effect of these changes on wetland environment benefit values (ESVs). The comes about highlight the misfortune of ESV due to LULC changes and emphasize the require for reclamation and maintainable administration of wetlands in urban and peri-urban regions (Assefa, 2021).

Javaid (2023) investigate investigates the impacts of urban development (LULC changes) on the warm environment (Arrive Surface Temperature) in Sialkot City, Pakistan. Utilizing partisan information traversing four unmistakable time periods (1989, 2000, 2009, and 2020), the think about predicts changes for the year 2030. The discoveries emphasize the significance of lessening human effect on nearby climate and analyzing urban populace development patterns (Javaid, 2023).

Yavari (2020) study quantifies and predicts water provision and habitat quality ecosystem services in wetlands. It analyzes the response of these services to land-use/land-cover changes. Although not specific to Rwanda, the insights can inform wetland conservation and management strategies. The ponder concludes that changes in wetland LCs have come about in varieties of the wetland ESs. This site-specific consider of the Contribute water surrender and living space quality models empowers us to investigate the appropriateness of spatially unequivocal modeling and recreating of wetland ESs to make strides wetland preservation and administration. The discoveries on the spatial temporal examination of wetland LCs and ESs can advance wetlands decision-making forms and taking compelling preservation activities (Yavari, 2020).

Değermenci (2023), the spatial and temporal representation of arrive utilize and arrive cover (LULC) changes makes a contrast to urge it the natural between typical regions and other ranges and to orchestrate for viability. Examine on the models utilized to choose the spatio-temporal change of LULC and amusement of conceivable future scenarios gives a point of see for future organizing and enhancement strategies. Landsat 5 TM for 1990, Landsat 7 ETM + for 2006, and Landsat 8 OLI for 2022 divided imageries were utilized to evaluate spatial and common assortments of move conceivable outcomes and future LULC reenactment. Free components (DEM, slant, and divisions to boulevards and buildings) and the cellular automata artificial neural organize (CA-ANN) illustrate facilitates inside the MOLUSCE plugin of QGIS were utilized. The CA-ANN appear was utilized to anticipate the LULC maps for 2038 and 2054, and the comes almost suggest that manufactured surfaces will continue to amplify. The DÃ¼zce City center's fake surfaces created by 100% between 1990 and 2022, from 16.04 to 33.10 km2, and are expected to be 41.13 km2 and 50.32 km2 in 2038 and 2054, separately. Fake surfaces, which secured 20% of the think almost locale in 1990, are evaluated to cover 64.07% in 2054. In case this float continues, most of the 1st-class provincial lands may be lost. The studies come approximately can offer assistance adjacent governments in them arrive administration techniques and offer assistance them in orchestrating for the long run. The comes approximately prescribe that approaches are essential to control the expansion of made surfaces, ensuring an balanced scattering of arrive utilize (Değermenci, 2023).

Yansui (2008) Based on the relate of the regional establishment of urban-rural transformational progression and examinations on the spot, this paper talks around the all-encompassing circumstance, winning components and instrument of arable arrive hardship and arrive for improvement occupation inside the coastal run of China over the ultimate decade, with the assistance of GIS development. Conclusions of the ask almost are summarized as takes after: (1) the arable arrive had been determinedly reducing from 1996 to 2005, with a hardship of 1,708,700 hm2 and an typical decrement of 170,900 hm2 per year; (2) arrive for improvement extended 1,373,700 hm2, with an ordinary increment of 153,200 hm2 per year; (3) include up to zone of encroachment on arable arrive for advancement between 1996 and 2005 was 1,053,100 hm2, bookkeeping for 34.03% of the arable arrive mishap inside the same period, the rates of which utilized for mechanical arrive (INL), transportation arrive (TRL), common improvement arrive (RUL) and town advancement arrive (TOL) are 45.03%, 15.8%, 15.47% and 11.5%, independently; and (4) the alter of the increase of development arrive and encroachment on arable arrive inside the locale were significantly influenced by the nation's doubtlessly obvious land-use approaches and advancement level of regional economy. The improvement of masses and movement of advancement progressed the speedy industrialization, development of transportation systems, provincial urbanization and improvement of common settlements inside the eastern coastal extend, and in this way were the basic driving qualities of land-use alter (Yansui, 2008).

While not directly related to Bahimba wetland, this study focuses on spatio-temporal change analysis and prediction of land use and land cover changes. It employs a Cellular Automata Artificial Neural Network (CA-ANN) model, which could be relevant for similar analyses in Rwanda. Although not specific to Rwanda, this study examines land-use conversion patterns and their impact. It provides insights into how land-use changes affect ecosystems and can serve as a reference for similar study. This study investigates land-use changes in the Yangtze River Delta. While not directly related to Rwanda, it offers valuable insights into spatio-temporal patterns and drivers of land-use change (Carvalho, 2022).

Although not specific to Bahimba wetland, this study analyzes spatio-temporal changes in land use/cover and their impact on land surface temperature. It establishes correlations with vegetation indices and snow indices. While not directly related to Rwanda, this study assesses the impact of LULC changes on wetland ecosystem services in the Lake Tana basin. The findings may offer insights applicable to other regions. Although focused on the Nile Delta, this study explores the effects of land use change on wetland degradation. The methodology and findings could be relevant for similar assessments in Rwanda. While not specific to Bahimba wetland, this study demonstrates how remote sensing and GIS can assess wetland degradation. The approach may be useful for studying wetlands in Rwanda (Ervin, 2021).

4. Conceptual framework of the study

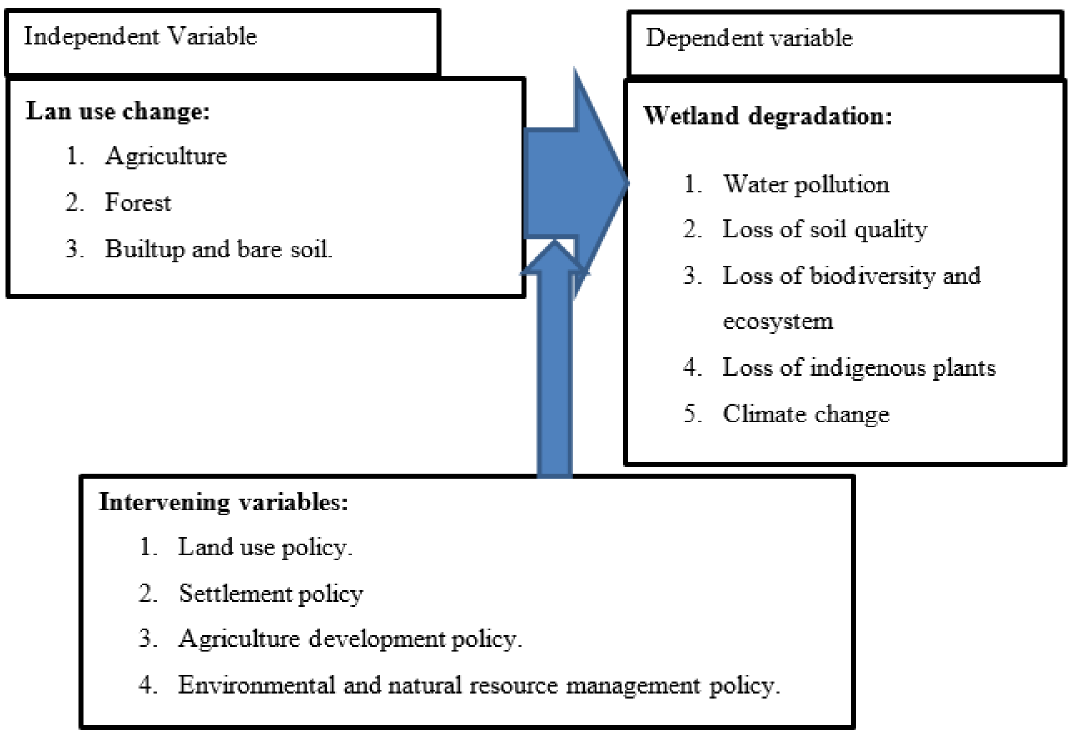
Wetlands, those biodiverse and invaluable ecosystems, play a crucial role in enhancing water quality, providing recreational opportunities, and supporting biodiversity. However, they face significant threats due to land-use and land-cover changes. Let's delve into the impact of these changes on wetland ecosystem services:

(1) Temporal and Spatial Changes: Over a span of 35 a long time (1984 to 2019) in Bahir Dar City, Ethiopia, wetlands and water bodies diminished by 75.71% (1618 hectares), whereas built-up ranges expanded by 216.24% (2599 hectares). Developed arrive at first expanded from 1984 to 1994 but continuously declined from there on (Belayneh, 2020). These land-use changes brought about in a decrease within the add up to environment benefit values (ESVs) provided by wetlands. The entire ESV diminished from USD 29.73 million to USD 20.84 million amid this period, speaking to a misfortune of about USD 8.9 million (Degife, 2019).

(2) Impact on Ecosystem Services: All person biological system administrations experienced negative changes. Outstandingly, administrations related to water direction, squander treatment, and territories for keeping up biodiversity endured the most prominent decrease. The development of built-up regions in Bahir Dar City essentially contributed to the misfortune of ESV (Biological system Administrations Esteem) given by wetlands (Desta, 2020).

(3) Implications: The decay in ESV due to LULC (Arrive Utilize and Arrive Cover) changes adversely influences nearby climate, squander administration, and the jobs of the destitute community. Rebuilding and maintainable administration of wetlands in urban and peri-urban regions are basic to moderate these impacts. In rundown, recognizing the financial esteem of wetland biological system administrations is pivotal for educated decision-making and preservation endeavors. There's a have to be the entire world populace to work together to ensure these crucial environments (Wondie, 2021).

Figure 1: Conceptual Framework of the Study



Source: Compiled by the researcher, 2024

5. Methodology of the study

Methodology shows techniques and methods that used during the study. It gives the background against which data was collected, assessed, and analyzed. It presents the research design, study population, sample size, sampling methods, data collection methods and instruments, procedure for data collection validity and reliability, data management and analysis and measurement of variables:

5.1 Reserch design

This study is mixture of qualitative and quantitative study design as intends to use both quantitative and qualitative data either from primary and secondary sources of data. This study is descriptive and correlational design. This study adopts a descriptive approach on describing the land use change activities (mainly human economic activities) and characteristics explaining Bahimba Wetland degradation. Descriptive study design is chosen because it enables to count frequency at which a certain assessed item was observed and gives summary as the mean and standard deviation are easy to interpret. This study is also correlative because it brings out clearly to establish the association between land use change and wetland degradation.

5.2 Study area

The study was carried out in the area of the Bahimba wetland, situated in Rulindo district. Rulindo District is one of the five districts comprising the Northern Province of Rwanda, alongside Gakenke, Burera, Gicumbi, and Musanze. Geographically, Rulindo lies in the northern part of the country, with a latitude of 2°9’17"S and a longitude of 30°0’27"E. The district is predominantly characterized by hills, including Tare, Tumba, and Cyungo, with elevations reaching up to 2,438 meters. These hills are interspersed with valleys and swamps that serve as habitats for rivers such as Nyabarongo, Muyanza, and Nyabugogo (Rulindo District, 2018).

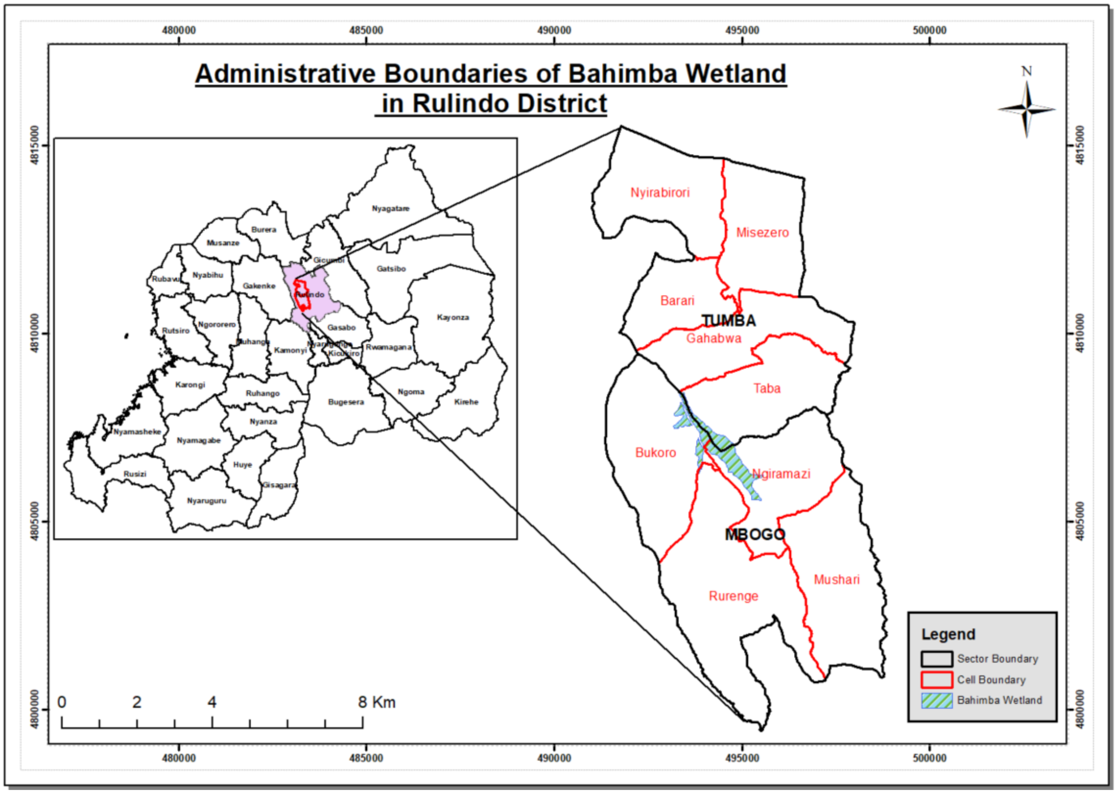


Figure 2: Map of the study area (CGIS, 2016)

Bahimba wetland is located in two sectors namely Tumba and Mbogo. In wide sense, it covers five sectors namely Mbogo, Tumba, Bushoki and Rusiga in Rulindo District, and Base Sector in Gakenke District. This study will consider the narrow sense, which is the biggest part of Bahimba wetland located in Ngiramazi and Bukoro Cell of Mbogo sector and in Taba cell of Tumba sector as shown in the map below (Figure 2).

The fact that this study will focus on Bahimba wetlands, makes 4 cells most important to the study as well. These are the cells in the neighborhoods of the wetland, with direct effects on its resources. The cells are Bukoro, Ngiramazi and Rurenge cell of Mbogo Sector and Taba Cell of Tumba sector.

5.2 Study population

The ponder populace is known as a well-defined collection of people or objects known to have comparative inquire about characteristics. Populace is the number of people or objects secured by the ponder or with which the think about is concerned (Grodowitz, 2018). To determine the study population for this study, the study has selected household’s beneficiaries of Bahimba wetland in mentioned cells surrounding Bahimba wetland. The cells are Bukoro, Ngiramazi and Rurenge cell of Mbogo Sector and Taba Cell of Tumba sector. This comprise 3,198 farmers in the cells mentioned above doing farming activities in Bahimba wetland in addition to 12 target population for interview (see more details in Table 3.1 how are distributed in cells).

As the population was large, the study has applied the use of Slovin sample size formula to determine sample size. Here n=N/(1+(N*(e2)) and by replacing the values at 95% level of significance the sample size become n=3,198/(1+(3,198*(0.052)) = 355.53 which is rounded to 356 households beneficiaries of Bahimba Wetland.

Table 1: Distribution of respondents

Population category	Total Population	Sample size	Sampling Technique
District/ Sector/ Cell/ Institution			
Population to respond the questionnaire			
Mbogo Sector	**2466**	**274**	Purposive sampling and Simple random sampling (Both probability and non-probability sampling)
Bukoro Cell	982	109	
Ngiramazi Cell	855	95	
Rurenge Cell	629	70	
Tumba Sector	**732**	**82**	
Taba Cell	732	82	
Sub-Total	***3,198***	***356***	
Population to be interviewed			Purposive sampling
Cells Executives (4 cells)	4	4	
Land Officers at Sector level (2 sectors)	2	2	
Environmentalist and urban planner at district level	2	2	
REMA	1	1	
Ministry of Environment	1	1	
NLA	1	1	
RFA	1	1	
Sub-Total	***12***	***12***	
Grand Total	**3,210**	**368**	**N/A**

Source: Nyandungu Eco-Park Management, REMA, Gasabo 3D and Afrilandscape (2024).

Currently sampled sectors and cells has more households and population, but using the purposive sampling (non-probability sampling) the study has identified only 4 cells from two sectors and not all households from these sectors and cells but only households actively having farming activities in the Bahimba Wetland. From various institutions also only institutions and employees working in functions related to wetland management and conservation as well as land use management in Rwanda (all these institutions are well listed in table 3.1). To select the households, random sampling was used from the household's members present in the wetland during the field visit, however anyone refused to respond the was replaced by any other willing to respond the.

5.3 Instrument of data collection

In William's (2021) perspective, a questionnaire is described as a valuable tool for intensive interviewing. It serves the purpose of collecting data that can be compared across all respondents, while also capturing information that is tailored to each individual's unique experiences and perspectives. The study employed a variety of question types, including open-ended, closed-ended, scaling, and dichotomous questions. Additionally, the questionnaire was designed to include both closed and open-ended items which was addressed to 356 household's beneficiaries of Bahimba wetland sectors of Tumba and Mbogo in Rulindo district.

The questionnaire has scaling questions due to its format where either the respondent chose 1, 2, 3, 4 and 5 (Strongly Disagree, Disagree, Not Sure, Agree and Strongly Agree respectively). The above scales were made to all indicators under independent and dependent variables as well as intervening variables (see the conceptual framework of the study). Among 356 targeted sample all have attended as any refused to respond the was replaced as the population was large.

Documentation or desk review was used to get necessary secondary data. The main consulted institutions and reports as well as tools used were all explained mainly during the assessment of land cover change and wetland degradation indicators. To get supplementary or additional information necessary to verify the secondary and primary data collected using closed ended questions. Here list of open questions were addressed 12 purposively sampled employees from institutions in charge of wetland management such as Rulindo district itself, REMA, Ministry of environment, NLA and RFA. Field observation is a qualitative study method that involves studies immersing themselves in a specific setting to make structured observations. These observations are then coded and used to identify themes within the study project (Assefa, 2021). This is very important tool which used for evaluating the quality for secondary data, primary data, to check whether at the field they are several facts to confirm that there is effect of land use change cover and wetland degradation.

5.4 Data Analysis

Data analysis was based on quantitative non-geo-spatial data and geo-spatial data and qualitative data analysis. Non-geospatial quantitative analysis was performed using descriptive statistics and inferential statistics (Bivariate and linear regression model) with support of Ms. Excel and Statistical Package for Social Sciences (SPSS). To analyze and interpret geo-spatial data, GIS and Remote Sensing techniques were used. GIS and remote sensing techniques help to process both Orthophotos and satellite images, to map and analyze the spatial-temporal dynamics of land use change of Rulindo district on Bahimba wetlands, with a focus on Bahimba wetland and TerrSet was used for processing and interpreting remote sensing image time series. And qualitative data was analyzed using recoding and summarizing the ideas from respondents and were presented as views of respondents.

Bivariate Correlation analysis was used for testing the validity of study questions, this ensures test of one dependent variable to one independent variable. Bivariate analysis, one of the simplest forms of statistical examination, aims to determine whether there exists a relationship between two sets of values. Typically, this analysis involves studying the variables X and Y. When conducting bivariate analysis, we calculate the Pearson Correlation, which can range from -1 to +1. The strength of this correlation whether positive or negative depends on the test results. Additionally, we consider the Sig.(2-Tailed) value, which assesses the statistical association between the tested variables. For results to be statistically significant, Sig.(2-Tailed) should be less than or equal to 0.05. Table 3.2 outlines various levels and categories of statistical analysis.

The study also used linear regression model for assessing the validity of study questions of the study. Here below is the linear model function:

$$Y=\beta_0+\beta_1 X_1+\beta_2 X_2+\beta_3 X_3+\varepsilon$$

where:

Y: Wetland degradation (which detailing or summarizing 5 indicators under dependent variable such as: water pollution, loss of soil quality, loss of biodiversity and ecosystem, loss of indigenous plants and climate change.

X1: Land for agriculture.

X2: Land Forest.

X3: Land for Builtup and bare soil.

β_1- β_3: Slope or coefficient of estimates.

6. Findings

Findings presentation in form of descriptive statistics was made using parameters like total sample, minimum, maximum, mean, significance, standard deviation and comment. Descriptive statistics parameters play important role to analyze or assess the perception of respondents on each item assessed either from independent and dependent variables.

6.1 Dynamics of land use change in the area of Bahimba wetland since 2000-2020

In this section, the study has assessed the land ownership in Bahimba wetland, period of time lasted in doing farming activities in wetland, kind of activities being developed in wetland, change of production over three years and reasons production of farmers has decreased in last three years. Here below are details:

Table 2: Assessment of land use change in Bahimba wetland

Items assessed	N	Min.	Max.	Mean	Stdv.	Comment
Agriculture						
In Bahimba wetland land for agriculture activities was increased to meet increased population needs for food.	356	3	5	4.20	.560	Strong and not all Similar
New plants were introduced in Bahimba wetland since 2010 to 2020 as people need crop diversification.	356	2	5	4.13	.674	Strong and not all Similar
People doing agriculture in Bahimba wetland are not organized to manage land conservation.	356	3	5	4.13	.416	Strong and all Similar
Forest						
In Bahimba wetland land for forest was reduced to meet increased population needs for construction and agriculture extension.	356	3	5	4.43	.534	Strong and not all Similar
Forests products (trees) were catted for house construction and other people's needs	356	3	5	4.26	.537	Strong and not all Similar
There are no activities for forest and natural vegetation extension in Bahimba since 2000 to 2020.	356	2	5	4.01	.733	Strong and not all Similar
Builtup and bare soil.						
In Bahimba wetland land for Builtup and bare soil activities was increased to meet increased population needs .	356	4	5	4.10	.306	Strong and all Similar
In area surrounding Bahimba wetland people were increased and built houses for living.	356	4	5	4.55	.498	Strong and all Similar
People use soil from Bahimba wetland for crafts development and other construction sector needs.	356	4	5	4.43	.496	Strong and all Similar
Valid N (listwise)	**356**	**2**	**5**	**4.25**	**.528**	**Strong and not all Similar**

Keys: *Strongly agree (SA) was coded 5, Agree (A) coded 4, Not Sure (NS) coded 3, Disagree (D) coded 2, and Strongly Disagree (SD) coded 1. The mean classification was into 3 categories such as weak (1.00-2.49), moderate (2.50-3.49) and strong (3.50-5.00) and standard deviation was into two categories such as homogeneity (Stdv. <0.5) and heterogeneity (Stdv. >0.5). N: Total Sample size (respondents), mean: Average of perception from all 356 perceptions as coded in numbers and Stdv: Standard deviation which signify gap between individual perception from the general perception or mean. Min: is the minimum choice on item assessed and Max is the maximum choice.*

As seen from Table 2, the perception of 356 sampled farmers in Bahimba wetland confirm that in Bahimba wetland land for agriculture activities was increased to meet increased population needs for food (3 Min, 5 Max, 4.2 Mean, 0.56 Standard Deviation and Strong and not all Similar), new plants were introduced in Bahimba wetland since 2010 to 2020 as people need crop diversification (2 Min, 5 Max, 4.13 Mean, 0.674 Standard Deviation and Strong and not all Similar) and people doing agriculture in Bahimba wetland are not organized to manage land conservation (3 Min, 5 Max, 4.13 Mean, 0.416 Standard Deviation and Strong and all Similar). This means that, land for agriculture over the years was reduced in Bahimba wetland.

On the case of forest land cover in Bahimba wetland, the study confirms that, in Bahimba wetland land for forest was reduced to meet increased population needs for construction and agriculture extension (3 Min, 5 Max, 4.43 Mean, 0.534 Standard Deviation and Strong and not all Similar), forests products (trees) were catted for house construction and other people's needs (3 Min, 5 Max, 4.26 Mean, 0.537 Standard Deviation and Strong and not all Similar) and there are no activities for forest and natural vegetation extension in Bahimba since 2000 to 2020 (2 Min, 5 Max, 4.01 Mean, 0.733 Standard Deviation and Strong and not all Similar).

While assessing the change on the built up and bare soil, 356 assessed farmers in Bahimba wetland confirm that in Bahimba wetland land for Builtup and bare soil activities was increased to meet increased population needs (4 Min, 5 Max, 4. 1 Mean, 0.306 Standard Deviation and Strong and all Similar), in area surrounding Bahimba wetland people were increased and built houses for living (4 Min, 5 Max, 4.55 Mean, 0.498 Standard Deviation and Strong and all Similar) and people use soil from Bahimba wetland for crafts development and other construction sector needs (4 Min, 5 Max, 4.43 Mean, 0.496 Standard Deviation and Strong and all Similar).

This clearer compared to the findings in the study of Belayneh (2020) where assessed the major drivers of land user change and found that, these change are based on economic development needs and population growth. This study also confirms that, the main drivers of land change are linked to the agriculture need by the population which need to satisfy their families and also needs of forests products as well as need of soils materials and all these activities affect the original wetland land coverage (Belayneh, 2020).

6.2 Major drivers of land use change in the area of Bahimba wetland and their effect on its natural resources especially land forest

In this section, the study has assessed the perception of respondents on the extent to which land use change in Bahimba wetland have affected water quality, soil quality, biodiversity and ecosystem services, indigenous plant life and climate change:

Table 3: Perception of respondents on the Performance of atmospheric pollution reduction

Items assessed	N	Min.	Max.	Mean	Stdv.	Comment
Water pollution						
Increased of population in and surrounding Bahimba wetland has contributed to the water pollution as some people drop waste in the wetland.	356	4	5	4.28	.449	Strong and all Similar
Increased soil exploitation in Bahimba wetland has reduced water quantity and quality.	356	3	5	4.13	.639	Strong and not all Similar
Deforestation and plant poor management in Bahimba wetland has made poor water quality.	356	4	5	4.28	.449	Strong and all Similar
Loss of soil quality						
Plantation of various plants which are not selected vis a vis the nature of soil has exhausted soil quality of Bahimba wetland.	356	4	5	4.43	.496	Strong and all Similar
Deforestation of plants has removed the natural fertility of soil from natural wetland plants.	356	2	5	3.70	.899	Strong and not all Similar
Use of different and non-tested fertilizers in Bahimba wetland for agriculture has reduced soil quality and natural resistance same case bare soil use.	356	4	5	4.15	.362	Strong and all Similar
Loss of biodiversity and ecosystem						
Deforestation has made different species leaving the Bahimba wetland.	356	3	5	4.44	.555	Strong and not all Similar
Human activities mainly agriculture has made water small animals and insects leaving the wetland.	356	2	5	4.03	.430	Strong and all Similar
Increased Builtup and bare soil has made ecosystem services change in Bahimba wetland.	356	2	5	4.43	.687	Strong and not all Similar
Loss of indigenous plants						
Deforestation has taken different natural trees to feed people's needs.	356	4	5	4.29	.453	Strong and all Similar
Increase of people has made people to use indigenous plants for cooking purposes and construction and this has made removal of some species.	356	4	5	4.40	.490	Strong and all Similar
The use of forest land for agriculture has made removal of different forest species and vegetation which were important to the wetland life.	356	2	5	3.81	.787	Strong and not all Similar
Climate change						
Bahimba wetland degradation and loss of biodiversity is an engine to climate change.	356	4	5	4.09	.282	Strong and all Similar
Loss of natural forest in the Bahimba wetland has reduced temperature resistance and wind.	356	4	5	4.53	.500	Strong and all Similar

Items assessed	N	Min.	Max.	Mean	Stdv.	Comment
Agriculture activity and drainage in Bahimba wetland has reduced humidity level in the area of.	356	4	5	4.17	.380	Strong and all Similar
Valid N (listwise)/ Average	**356**	**2**	**5**	**4.21**	**.524**	**Strong and not all Similar**

Table 3, indicate that on the extent to which land use change in Bahimba wetland lead to water pollution, findings from 356 sampled farmers in Bahimba wetland confirm that, increased of population in and surrounding Bahimba wetland has contributed to the water pollution as some people drop waste in the wetland (4 Min, 5 Max, 4.28 Mean, 0.449 Standard Deviation and Strong and all Similar), increased soil exploitation in Bahimba wetland has reduced water quantity and quality (3 Min, 5 Max, 4.13 Mean, 0.639 Standard Deviation and Strong and not all Similar) and deforestation and plant poor management in Bahimba wetland has made poor water quality (4 Min, 5 Max, 4.28 Mean, 0.449 Standard Deviation and Strong and all Similar).

By the extent to which land use change in Bahimba wetland has led to loss of soil quality, sampled 356 respondents confirm that plantation of various plants which are not selected vis a vis the nature of soil has exhausted soil quality of Bahimba wetland (4 Min, 5 Max, 4.43 Mean, 0.496 Standard Deviation and Strong and all Similar), deforestation of plants has removed the natural fertility of soil from natural wetland plants (2 Min, 5 Max, 3.7 Mean, 0.899 Standard Deviation and Strong and not all Similar) and use of different and non-tested fertilizers in Bahimba wetland for agriculture has reduced soil quality and natural resistance same case bare soil use (4 Min, 5 Max, 4.15 Mean, 0.362 Standard Deviation and Strong and all Similar).

On the extent to which land use change in Bahimba wetland has affected and led to loss of biodiversity and ecosystem, 356 sampled respondents confirm that, deforestation has taken different natural trees to feed people's needs (3 Min, 5 Max, 4.44 Mean, 0.555 Standard Deviation and Strong and not all Similar), increase of people has made people to use indigenous plants for cooking purposes and construction and this has made removal of some species (2 Min, 5 Max, 4.03 Mean, 0.43 Standard Deviation and Strong and all Similar) and the use of forest land for agriculture has made removal of different forest species and vegetation which were important to the wetland life (2 Min, 5 Max, 4.43 Mean, 0.687 Standard Deviation and Strong and not all Similar).

On the extent to which land use change has affected Bahimba wetland via loss of indigenous plants, the findings from 356 respondents confirm that, deforestation has taken different natural trees to feed people's needs (4 Min, 5 Max, 4.29 Mean, 0.453 Standard Deviation and Strong and all Similar), increase of people has made people to use indigenous plants for cooking purposes and construction and this has made removal of some species (4 Min, 5 Max, 4.4 Mean, 0.49 Standard Deviation and Strong and all Similar) and the use of forest land for agriculture has made removal of different forest species and vegetation which were important to the wetland life (2 Min, 5 Max, 3.81 Mean, 0.787 Standard Deviation and Strong and not all Similar).

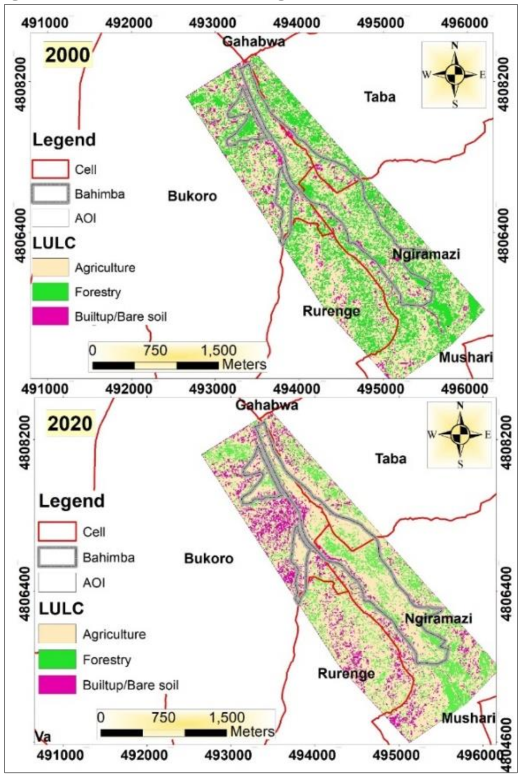
On extent to which land use change in Bahimba wetland has contributed in Climate change, findings from 356 respondents confirm that Bahimba wetland degradation and loss of biodiversity is an engine to climate change (4 Min, 5 Max, 409 Mean, 0.282 Standard Deviation and Strong and all Similar), loss of natural forest in the Bahimba wetland has reduced temperature resistance and wind (4 Min, 5 Max, 4.53 Mean, 0.500 Standard Deviation and Strong and all Similar) and agriculture activity and drainage in Bahimba wetland has reduced humidity level in the area of (4 Min, 5 Max, 4.17 Mean, 0.38 Standard Deviation and Strong and all Similar).

The findings here confirm that, the change of land for agriculture (which increased), land for forestry (reduced) and land for Builtup and bare soil (increased) have modified the original coverage of Bahimba wetland. This is similar but not perfect to the study of Değermenci (2023), where mentioned that the change of land use on wetland should be in favorable way to the wetland nature not to the people's needs. Where he given an example of changing wetland land use by planting more trees, by allowing vegetation growth, by developing tourist sites and fishing ponds, etc. This is different to Bahimba wetland where people use land as they want and even some households have built houses in the original land coverage of Bahimba wetland and they used to handle household waste in the wetland (Değermenci, 2023).

Table 4: Land Use Change in Bahimba wetland

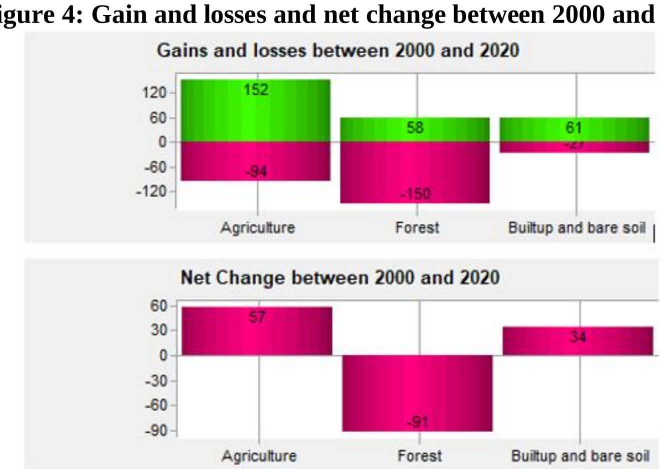
Year	**2000**		**2020**	
LULC	Area(Ha)	Area(%)	Area(Ha)	Area(%)
Agriculture	300.57	21.30	357.95	25.37
Forest	198.11	14.04	106.63	7.56
Builtup and bare soil	912.36	64.66	946.46	67.08
Total	1411.04	100	1411.04	100

Figure 3: Land Use Change in Bahimba wetland



The findings in table 4 and Figure 3 from the analysis of land use change within the Bahimba wetland in the Rulindo district from 2000 to 2020 reveal significant shifts in LULC categories. In 2000, agricultural activities covered approximately 300.57 Ha, constituting 21.30% of the wetland area, which increased to 357.95 Ha (25.37%) by 2020. Conversely, forested areas within the wetland experienced a notable decline, decreasing from 198.11 Ha (14.04%) in 2000 to 106.63 Ha (7.56%) in 2020. Builtup and bare soil areas witnessed a consistent rise, expanding from 912.36 km² (64.66%) in 2000 to 946.46 Ha (67.08%) in 2020. These findings underscore the substantial impact of land use change on the Bahimba wetland ecosystem, with agricultural expansion and settlements development contributing to the degradation of forested areas and alteration of natural habitats.

Figure 4: Gain and losses and net change between 2000 and 2020



The analysis in figure 4 reveals specific gain and losses in various land use and land cover (LULC) categories within the Bahimba wetland between 2000 and 2020. Agriculture experienced a net loss of 94 Ha from 2000 to 2020, while concurrently gaining 152 Ha. Forested areas within the wetland saw a substantial decline of 150 km² during the same period, accompanied by a gain of 58 km². Similarly, Builtup and bare soil areas witnessed a net loss of 27 Ha from 2000 to 2020, coupled with a gain of 61 Ha. These findings illustrate the dynamic nature of land use changes within the Bahimba wetland, characterized by both losses and gains across different LULC categories over the two decades.

Figure 5: Land surface size change 2000 to 2020 for Bahimba wetland in Tumba and Mbogo sector area

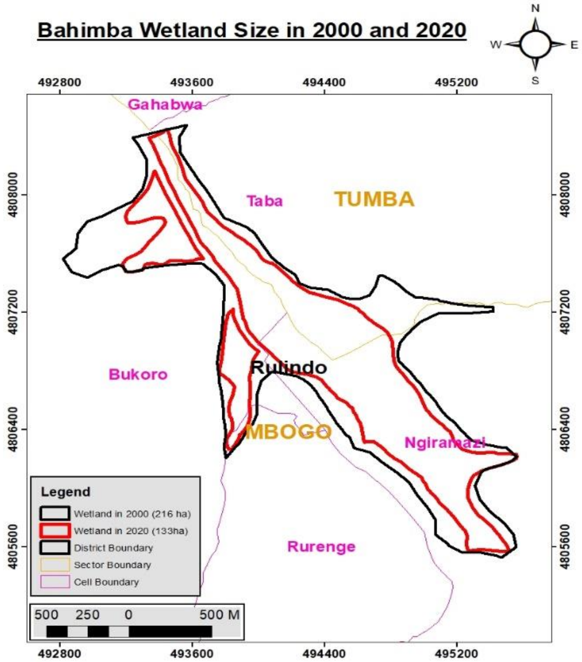


Figure 5 indicate that, according to land use change facts, Bahimba wetland size has reduced around 83 ha to feed human settlement or building and other economic infrastructures such as road and also to feed agriculture activities. This one among factors explaining wetland degradation as people could not built house in wetland but in the other sides.

6.3 Major drivers of land use change in the area of Bahimba wetland and their effects on its resources like land and forest.

In this section, the study assesses different facts on land use change and its effects on Bahimba wetland degradation by looking which activities farmers suggest can be implemented in Bahimba wetland, extent to which, extent to which land and forest in this wetland has lost their quality, respondents whose activities in Bahimba wetland contributed in the loss of land and forest quality, the cause of land and forest losing its quality for respondents whose activities do not contribute in wetland degradation, main effects of land use change on Bahimba wetland degradation, period at which people knows effects of land change on Bahimba wetland degradation, measures adopted by respondents as strategies of Bahimba wetland conservation and recommendations of respondents in what should be done to preserve the wetland.

Table 5: Perception of respondents on the policies awareness toward wetland management (mainly Bahimba wetland)

Items assessed	N	Min.	Max.	Mean	Stdv.	Comment
People beneficiaries of Bahimba wetland are aware about land use policy guiding use of wetland in Rwanda.	356	1	5	3.54	1.204	Strong and not all Similar
Households or people growing crops in Bahimba wetland are aware the settlement policy prevent people to build houses in the area of wetland.	356	1	5	3.36	.938	Strong and not all Similar
Households or people growing crops in Bahimba wetland are aware about the agriculture development policy and priorities of crops and fertilizers utilization.	356	1	5	3.48	1.017	Strong and not all Similar
Households or people growing crops in Bahimba wetland are aware about the environmental and natural resource management policy for natural resources management.	356	1	5	3.69	.940	Strong and not all Similar
Valid N (listwise)/ Average	**356**	**1**	**5**	**3.52**	**1.025**	**Strong and not all Similar**

Table 5 confirm that, from 356 sampled farmers in Bahimba wetland indicate that or confirm that people beneficiaries of Bahimba wetland are aware about land use policy guiding use of wetland in Rwanda (1 Min, 5 Max, 3.54 Mean, 1.204 Standard Deviation and Strong and not all Similar), households or people growing crops in Bahimba wetland are aware the settlement policy prevent people to build houses in the area of wetland (1 Min, 5 Max, 3.36 Mean, 0.938 Standard Deviation and Strong and not all Similar), households or people growing crops in Bahimba wetland are aware about the agriculture development policy and priorities of crops and fertilizers utilization (1 Min, 5 Max, 3.48 Mean, 1.017 Standard Deviation and Strong and not all Similar) and households or people growing crops in Bahimba wetland are aware about the environmental and natural resource management policy for natural resources management (1 Min, 5 Max, 3.69 Mean, 0.94 Standard Deviation and Strong and not all Similar).

Lan degradation always is happening even if policies and politics on land management and environmental protection are in place (Carvalho, 2022). This the same case as found in this study however the issue is based on change in climate where hill land remains inefficient to feed the family needs and people look for wetland soil. And also as people don't have capacity to finance agriculture or other economic activities they remain relaying on subsistence agriculture which is not friendly to wetland protection.

6.4 Correlation test between land use change and wetland degradation

As explained in methodology the inferential statistics was made via both bivariate correlation analysis and linear regression model. Both models were made using codes attributed to respondents' perceptions and these codes were used to calculate mean which represent the indicator assessed and the mean of the mean to present the variable assessed (both dependent and independent variable).

Table 6: Correlation between indicators on land use change and wetland degradation case of Bahimba wetland

		Water pollution	Loss of soil quality	Loss of biodiversity and ecosystem	Loss of indigenous plants	Climate change	Wetland Degradation	Land use and Wetland Management Policy
Agriculture	Pearson Correlation	.065	.225**	.164**	.176**	.142**	.131*	-.294**
	Sig. (2-tailed)	.223	.000	.002	.001	.007	.014	.000
	N	356	356	356	356	356	356	356
Forest	Pearson Correlation	.142**	.084	.242**	.368**	.455**	.176**	-.049
	Sig. (2-tailed)	.007	.113	.000	.000	.000	.001	.360
	N	356	356	356	356	356	356	356
Builtup and bare soil.	Pearson Correlation	.187**	.461**	.349**	.263**	.053	.224**	-.154**
	Sig. (2-tailed)	.000	.000	.000	.000	.320	.000	.004
	N	356	356	356	356	356	356	356
Land Use Change	Pearson Correlation	.184**	.115*	.191**	.395**	.306**	.122*	-.057
	Sig. (2-tailed)	.000	.030	.000	.000	.000	.021	.287
	N	356	356	356	356	356	356	356

Table 6 show that, there is a positive correlation for all tested indicators, specifically there is a positive correlation between change in land for agriculture to water pollution (6.5%) and this correlation is not statistically significant as depends on how the agriculture activities were implemented. Change in land for agriculture contribute 22.5% in loss of soil quality and this correlation is statistically significant ($p=0.000 < 0.01$), change in land for agriculture contribute 16.4% to loss of biodiversity and ecosystem and this correlation is statistically significant ($p=0.002 < 0.05$), change in land for agriculture contribute 17.6% to loss of loss of indigenous plants and this correlation is statistically significant ($p=0.001 < 0.05$), change in land for agriculture contribute 14.2% to loss of loss of indigenous plants and this correlation is statistically significant ($p=0.007 < 0.05$), change in land for agriculture contribute 13.1% to wetland Degradation in general and this correlation is statistically significant ($p=0.014 < 0.05$) and there is a negative correlation between change of land for agriculture (-29.4%) on land use and wetland management policies and this correlation is statistically significant ($p=0.000 < 0.01$).

On the side of land of forest change effect, the study results indicate that there is a positive correlation between change in land for the forest to water pollution (14.2%) and this correlation is not statistically significant ($p=0.007 < 0.05$). Change in land for the forest contribute 8.4% in loss of soil quality and this correlation is not statistically significant ($p=0.117 > 0.05$), change in land for the forest contribute 24.2% to loss of biodiversity and ecosystem and this correlation is statistically significant ($p=0.000 < 0.01$), change in land for the forest contribute 36.8% to loss of loss of indigenous plants and this correlation is statistically significant ($p=0.000 < 0.01$), change in land for the forest contribute 45.5% to loss of loss of indigenous plants and this correlation is statistically significant ($p=0.000 < 0.01$), change in land for the forest contribute 17.6% to wetland Degradation in general and this correlation is statistically significant ($p=0.001 < 0.05$) and there is a negative correlation between change of land for agriculture (-4.9%) on land use and wetland management policies and this correlation is statistically significant ($p=0.036 < 0.05$).

On the side of Builtup and bare soil land change effect, the study results indicate that there is a positive correlation between Builtup and bare soil land change to water pollution (18.7%) and this correlation is statistically significant ($p=0.000 < 0.01$). Builtup and bare soil land change contribute 46.1% in loss of soil quality and this correlation is statistically significant ($p=0.000 < 0.01$), Builtup and bare soil land change contribute 34.9% to loss of biodiversity and ecosystem and this correlation is statistically significant ($p=0.000 < 0.01$), Builtup and bare soil land change contribute 26.3% to loss of loss of indigenous plants and this correlation is statistically significant ($p=0.000 < 0.01$), Builtup and bare soil land change contribute 5.3% to loss of loss of indigenous plants and this correlation is not statistically significant ($p=0.320 > 0.05$), Builtup and bare soil land change contribute 22.4% to wetland Degradation in general and this correlation is statistically significant ($p=0.000 < 0.01$) and there is a negative correlation between change of land for agriculture (-15.4%) on land use and wetland management policies and this correlation is statistically significant ($p=0.004 < 0.05$).

On the side of land use change in general effects effect, the study results indicate that there is a positive correlation between Land use change in general to water pollution (18.4%) and this correlation is statistically significant ($p=0.000 < 0.01$). Land use change in general contribute 11.5% in loss of soil quality and this correlation is statistically significant ($p=0.03 < 0.05$), Land use change in general contribute 19.1% to loss of biodiversity and ecosystem and this correlation is statistically significant ($p=0.000 < 0.01$), Land use change in general contribute 39.5% to loss of loss of indigenous plants and this correlation is statistically significant ($p=0.000 < 0.01$), Land use change in general contribute 30.6% to loss of loss of indigenous plants and this correlation is statistically significant (p=0.000 > 0.05), Land use change in general contribute 12.2% to wetland Degradation in general and this correlation is statistically significant (p=0.021 < 0.05) and there is a negative correlation between change of land for agriculture (-5.7%) on land use and wetland management policies and this correlation is not statistically significant (p=0.287 > 0.05).

In normal way land use change in wetland is a tool toward wetland degradation where the wetland should be left by people for their natural beauty and capacity for biodiversity and ecosystem services (Huang Q. Z., 2019). This study shows that, people in Rulindo district mainly farmers in Bahimba wetland are their economic activities are not friendly to the Bahimba wetland original size and original land coverage.

Linear regression model analysis was made using average of respondent's perception on indicators or grouped indicators based on the variable either independent (land use change) or dependent (wetland degradation case of Bahimba).

Table 7: Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.283[a]	.080	.072	.1453761

a. Predictors: (Constant), Builtup and bare soil., Agriculture, Forest

As seen from table 7, the model had Adjusted R2 of 0.072, implies that Challenges of conducting Environmental Impact Assessment (EIA) (Land for agriculture or X1, Land Forest or X2, and Land for Builtup and bare soil or X3), explain 7.2% of wetland degradation or Y (Wetland degradation (which detailing or summarizing 5 indicators under dependent variable such as: water pollution, loss of soil quality, loss of biodiversity and ecosystem, loss of indigenous plants and climate change). While the remaining 92.8% (determinant) of wetland degradation are resulted from other factors that have not been captured in the model or in this study.

Table 8: Analysis of Variance (ANOVA)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.646	3	.215	10.184	.000[b]
	Residual	7.439	352	.021		
	Total	8.085	355			

a. Dependent Variable: Wetland Degradation

b. Predictors: (Constant), Builtup and bare soil., Agriculture, Forest

Based on the data from table 8, the statistical analysis reveals that the model achieved an F ratio of 10.184, with a P value of 0.000 (which is less than 0.05). This significant F ratio indicates that the overall regression model, encompassing all tested variables, is statistically significant and suitable for prediction at a 1% significance level. Furthermore, the predictor variables specifically, Land for agriculture (X1), Land Forest (X2), and Land for Builtup and bare soil (X3) demonstrate statistical significance in relation to wetland degradation (Y). Consequently, we can confirm that land use changes, including shifts in agriculture, forest, and Builtup areas, significantly impact water pollution, soil quality loss, biodiversity reduction, ecosystem disruption, and changes in indigenous plant populations, as well as climate alterations.

Table 9: Summary of coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.857	.176		21.927	.000
	Agriculture	.075	.026	.155	2.914	.004
	Forest	.060	.025	.144	2.431	.016
	Builtup and bare soil.	.094	.035	.153	2.656	.008

a. Dependent Variable: Wetland Degradation

In the context of Table 9, the positive sign of the beta (β) coefficient indicates that the independent variable's coefficients have a favorable impact on the dependent variable. The same table reveals that all beta values associated with the independent variable indicators are positive, implying a beneficial effect on the predicted dependent variable. $\beta 1=0.075$, $t=2.914$, $p=0.000<0.04$; $\beta 2=0.060$. $t=2.431$, $p=0.016<0.05$ and $\beta 3=0.094$, $t=2.656$, $p=0.008<0.05$. That means, any increase in the independent variables lead to increase in the dependent variable and vice versa. The regression model become as follows:

Y or wetland degradation = 3.857 + 0.075X1 + 0.060X2 + 0.094X3. Thus, the study concluded that Land for agriculture or X1, Land Forest or X2, and Land for Builtup and bare soil or X3 have positive effect on loss of wetland degradation. In other words, if these determinants are not available, wetland degradation will be equivalent to 3.857 units. This means that once wetland for agriculture main changing, forest land change and Builtup and bare soil land change goes in the same proportion to the wetland degradation.

Generally, wetland protection need prevention or management of human activities sin the area mainly agriculture activities, use of forests products, and use of soil for other purposes (Rwanyiziri, 2019). But in this study the findings show the different where people of Bahimba wetland beneficiaries remain using the wetland land for animal rearing, habitation and also for crop growing and taking the soil for different purposes.

4.3 General views of respondents and discussion of findings

The assessment on the open questions has resulted that at main level land use change has affected Bahimba wetland, where the original land covered for forest and vegetation has change over the years, land for agriculture increased over the years and some people come to build house in the wetland and some other throw waste in the wetland. The assessment also confirms that, the measures for wetland conservation were not reinforced except few measures for farming in cooperatives, reducing people extracting soil in the wetland and limiting people also exploiting forest trees.

On the side how farmers and people around the Bahimba wetland understand and respect wetland conservation measures, this was found in negative way, where people want to work as they want and want to use more forest resources without planting others and ensuring individualism in farming. Here also sometimes lower income capacity made some people to failure to comply with wetland and environmental compliance measures. Today there are no measures or punishment in place for people who failure to comply with policies.

To ensure that Bahimba wetland, restoration is made, there is a need to limit agriculture activities, limiting people exploiting forest and various vegetation, limiting people taking soil in the wetland, and planting new plants, protecting water and also adoption of exotic plants where possible and make the wetland more useful and make it modernized for tourism and fishing activities.

Figure 6: Bahimba wetland 2017

Source: Google earth, extracted April 2024

The figure 6 show that there are households living in the buffer zone of Bahimba wetland. Currently in Rwanda measures for wetland protection are not well communicated to the population as not all people have capacity to understand this phenomenon. It seems to be a complicated phenomenon to understand because most people doing subsistence agriculture are not skilled enough to understand how human activities affect wetland degradation and later lead to water pollution, soil quality and climate change. Here awareness on radios, television, booklets and other dissemination tools are not sufficient there is a need to ensure also field awareness and meeting farmers in the area of to show how was changed over the years so they can understand what to do in the future.

7. Conclusion

Wetlands are crucial ecosystems that provide a wide range of benefits, both locally and globally. These benefits include enhancing water quality, supporting biodiversity, and offering recreational opportunities. However, wetlands often face degradation due to human activities, including land use changes. Understanding the impact of such changes is essential for informed decision-making. The impact of land-use and land-cover (LULC) changes on wetland ecosystem service values (ESVs) has far-reaching consequences. These changes not only affect the environment but also have negative implications for local climate, waste management, and the livelihoods of communities. To mitigate these effects, it is crucial to prioritize interventions that focus on the restoration and sustainable management of wetlands in both urban and rural areas. This study underscores the importance of balancing development with environmental conservation, especially in wetland ecosystems. By understanding the consequences of land use changes, we can make informed decisions to protect these valuable natural resources.

The study findings reveal that the model exhibited an F ratio of 10.184 with a P-value of 0.000 (which is less than 0.05). This indicates that the F ratio is statistically significant. Consequently, the overall regression model, encompassing all the tested variables, is also statistically significant and can be employed for prediction at the 1% significance level. Furthermore, this underscores that the predictor variables specifically, Land for agriculture (X1), Land Forest (X2), and Land for Builtup and bare soil (X3) are statistically significant in relation to wetland degradation (Y). therefore, it is confirmed that there is a significant effect of land use change on wetlands degradation (agriculture land use change, forest land change, Builtup and bare soil land change has significant effect on water pollution, loss of soil quality, loss of biodiversity and ecosystem, loss of indigenous plants and climate change).

8. Recommendations

Due to the study findings, the study suggests recommendations to the institutions in charge of wetland management, farmers in wetland and other studies.

8.1 To the institutions in charge of wetland management

It was found that, there is low rate of awareness toward land use policies, agriculture policies, environmental and natural resources management policies as well as settlement policies which made people constructing houses in Bahimba wetland and other uncontrolled economic activities in wetland. Due to that, the management are encouraged to improve the awareness and also develop strong measures like wetland restoration to ensure that the biodiversity, water and ecosystem are in good health.

8.2 To the farmers in Bahimba wetland

There is a number of farmers in Bahimba wetland who do not know or agree about their role in wetland degradation as results of their activities. Thus, they should take time themselves to learn and to change the way they are exploring Bahimba wetland, to ensure that they are getting profit with conserved wetland.

8.3 To other studies

This study was limited on the Spatio-temporal analysis of the effects of land use change on wetlands degradation in Rwanda from 2000 to 2020. The case of Bahimba wetland in Rulindo district. Other studies are encouraged to assess same topic to other wetlands in Rwanda and or to expand the scope and predict what will happen in the future with several scenarios on the case of human activities.

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