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Analysing the Impacts of Rusizi Urban Growth on Kivu Coastline: Evidence in Gihundwe and Kamembe Sectors

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Abstract

Rwanda has emphasized on the acceleration of urbanization from 18.4% (2016/17) to 35% by 2024 and to 50% by 2050. Urban growth is always coupled with adverse effects on land, forest, and water bodies as result of construction activities, agriculture, water discharge and industrialization. This study intended to assess the factors promoting Rusizi urban growth and related impacts on lake Kivu coastline. Water samples were studied by analyzing biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN), pH and total phosphorus (TP). Besides, questionnaires and interviews were given for survey. The findings revealed that agricultural activities carried out in Gihundwe and Rusizi Sectors, water pollution caused by fertilizers, pesticide and herbicides used in agriculture, soaps from car wash, improper disposal of domestic wastes. In addition, domestic and industrial waste waters discharged into lake Kivu could be a serious threat to ecosystem of the coastline because of high increase of BOD level, where a BOD level of 336 mg/L was tested from Kivu compound, while Budiki swamp discharges BOD of 448 mg/L, Gatandara river discharges 380.8 mg/L and Kadasomwa river 504 mg/L which are beyond the standard level of 50 mg/L. The study also revealed that sedimentation from construction, contamination of water of the lake caused by oil and chemical spills from ship building and water transport could have severe effects of the coastline of lake Kivu. The study recommends that the government of Rwanda, through the Ministry of Environment and local authorities, should strictly enforce environmental laws and urban planning regulations in Rusizi district to mitigate the negative impacts of urban growth on the Lake Kivu coastline. Additionally, it is recommended that educational institutions and research bodies increase their focus on developing sustainable urbanization strategies and innovative waste management solutions tailored to the unique challenges of rapidly growing urban areas near sensitive water bodies.

Keywords: *Urbanization; Coastline, Soil erosion; Pollution; Migration.*

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1.0 Introduction

Lake Kivu is the smallest of the African Great Lakes belonging to the Albertine Rift with a catchment location of about 7000 km^2 (Aaberg, 2013). The lake is placed at the border among Rwanda and Democratic Republic of Congo, among 1 °30′ and 2° 30′South and 28°50′ and 29°23′ East alongside the East-African Rift. Lake Kivu covers a floor location of seven hundred km^2 with an altitude of 1,460 meters above sea stage and it's bordered by 5 districts Rubavu, Rutsiro, Karongi, Nyamasheke and Rusizi from North to the south (REMA, 2014). Rwanda has experienced a quick urban development with yearly urban development (4.5 %) generally surpassing the worldwide normal (1.8%) (REMA, 2015). The nation is one of the thickly populated nations of Africa with populace thickness of 495 inhabitants/km2 in 2018, thus, fast urbanization and populace development posture genuine dangers on wetland assets in both country and urban regions (Rwanyiziri, 2020).

Further, like other African lake, lake is prone to human activities like the increasing subsistence agricultural activities, deforestation, and urbanization. These have had detrimental effects to the security of this lake, for instance; deforestation has led to erosion and landslides into the lake which increased nutrient inputs hence threatening the aquatic life (Aaberg, 2013). additionally, it's also proved that rivers and streams which drain into lake are very turbid and brown colored because of the abundant phytoplankton and suspended organic matter resulting from agricultural activities which further contributes to the nutrient inputs into the lake (Aaberg, 2013).

Furthermore, different studies have revealed that the presence of garbage dumps in urban and suburban areas hinders the event of economic and tourist activities as they reduce the standard of living. this is often because poorly managed and badly located dumps and landfills cause unsightly, smelly and might contaminate soil, groundwater, and streams (WGEA, 2013).

More so, Rwanda through its National Strategy Transformation (NST1) has been committed to accelerate Sustainable Urbanization from 18.4% (2016/17) to 35% by 2024 (GoV, 7 Years Government Programme: National Strategy for Transformation (NST1) 2017-2024, 2017). However, human activities in urban areas have led to the loss of forest cover, encroachment on wetlands, lakeshores, and riverbanks, including poor land use practices which resulted into eating away and siltation of our water bodies (Mafaranga, 2020). Thus, this study aims to research human influenced changes and their impacts on Kivu coastline in Rusizi District to fill the gap of the scarcity of research showing how anthropogenic activities have adverse effects on lake coastlines in Rwanda. The study is conducted in Gihundwe and Kamembe sectors of Rusizi district because the core areas of Rusizi city where many activities like trade, hotels, hospitals, transport, settlements, agriculture, fishing, and ship building are concentrated. The above areas are drained by three rivers namely Kadasomwa, Gatandara and Gitinda which radiate their water in Kivu.

Therefore, taking into consideration sustainable development goal eleven which aims to form cities and human settlements inclusive, safe, resilient, and sustainable. This study will assess the impacts human activities on the coastline of lake, where scientific approaches to live salinity and alkalinity of water (PH), biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN) and total phosphorus (TP) concentrations are going to be tested as important parameters to work out the standard of water bodies and to manage the water quality. The findings of the study also should provide relevant information to the ministry of environment, local leaders, local population, and high learning institutions on sustainable development of urban areas of Rwanda without compromising the coastlines of lakes.

2.0 Materials and methods

2.1 Study area

Rwanda's Western Province contains the District of Rusizi. The largest city in Rwanda's Southern Western Province and its capital is Kamembe. The region is located where Lake Kivu empties into the Ruzizi River, which then drains into Tanganyika Lake at the southern end of the lake. Along with Karongi and Rubavu, Rusizi is one of the three important Rwandan Lake Kivu ports, all of which are in the Rusizi District. Congolese from Bukavu city in the Democratic Republic of the Congo (DRC)

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frequently visit Kamembe City. The district also contains the western half of Nyungwe National Park, a tourist attraction, with Cyamudongo Reserve, a home of chimpanzees as well as many other species of primate edit and other tree species. Bugarama, Butare, Bweyeye, Gikundamvura, Gashonga, Giheke, Gihundwe, Gitambi, Kamembe, Muganza, Mururu, Nkanka, Nkombo, Nkungu, Nyakabuye, Nyakarenzo, Nzahaha, and Rwimbogo are the 18 sectors that make up the Rusizi district.

The research was conducted in Kamembe sector and Gihundwe sectors, as they are the ones on the coastline of Lake Kivu, as shown in the Figure below (Fig.1).

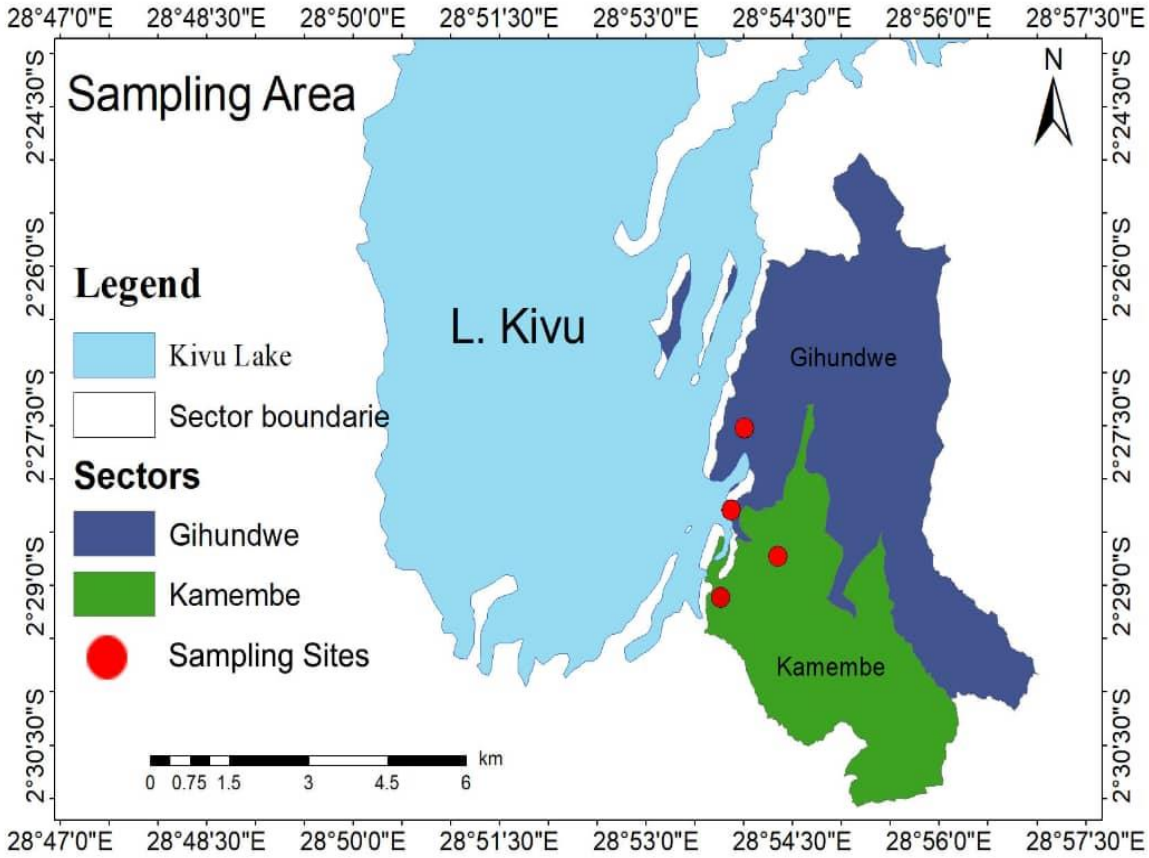

Figure 1:Map of Rusizi District showing Gihundwe sector(right) and Kamembe soctor (left) Source:Hakorimana Egide (UNILAK, GIS&RS Laboratory).

2.2 Materials

2.2.1 Preparations for water parameters measurement

(a) Biological oxygen demand (BOD)

The BOD was calculated in this research by using four 300 ml BOD bottles, adding 10 ml of samples to two of the bottles. BOD, a reliable indicator for the level of organic pollution in water, was quantified as milligrams of oxygen used per liter of sample (mg/l) for five days of incubation at 20°C.The following formula are used to determine the lowest and maximum estimated dilution:

i. ml sample added to BOD bottle = (minimum allowable depletion, mg/l x Volume of BOD bottle, ml)/estimated BOD, mg/l.
ii. ml sample added to BOD bottle = (maximum allowable depletion, mg/l x Volume of BOD bottle, ml)/estimated BOD, mg/l.

(b) pH of water

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One of the most crucial variables in water chemistry, it is evaluated as the strength of acidity or alkalinity on a scale from 0 to 14 and is defined as -log [H+]. The pH of natural waters, which is primarily basic and ranges from 4.5 to 8.5, is controlled by the equilibrium between carbon dioxide, bicarbonate, and carbonate ions. In order to support the nature of the pollutant, wastewater and polluted natural waters have pH values that are lower than or higher than 7. pH of water was measured using a pH meter to see the number of hydrogen ions that's present within the water. Colorimetric method for pH of Water was used where the colorimetric paper was dipped on the sample of water and consequently, the resulting color was calculated using the quality table, and the corresponding pH value was noted. Thus, it was determined by the pH value whether the water sample was acidic or alkaline.

(c) Chemical oxygen demand (COD)

A Nessler's tube is filled with a reagent consisting of 15ml of concentrated sulfuric acid, 0.3g of mercuric sulphate, a pinch of silver sulphate, and 5ml of 0.025M salt. Pipette 10ml of the sample (after giving it a good shake) into this mixture, and then leave it there for 90 minutes to allow for digestion. Using ferroin indicator, the mixture is titrated against 0.25M FAS until the color changes from blue green to wine red, marking the top point. 40ml of water is then added to the cooled liquid (to make up to 50ml). A reagent blank is additionally dispensed using 10ml of water. Thus, COD was wont to determine the amount of pollution in water, the upper value of chemical oxygen demand was detected to point the amount organic pollution in water sample.

(d) Total Nitrogen (TN)

Determining Total nitrogen (TN) levels in process water and wastewater is incredibly important in evaluating water quality. This is often because TN concentration has severe impact on eutrophication of water sources. Thus, the subsequent formula was used:

Total Nitrogen = TKN + NO_2 + NO_3

Total Kjeldahl Nitrogen, or TKN, is the sum of Ammonia Nitrogen (NH3) and Organic Nitrogen (ORN). Urea and acid are two examples of organic nitrogen, which is primarily found as amino acids and proteins. Nitrite, nitrate, and nitrogen gas are all abbreviated as NO_2, NO_3, and N_2, respectively.

(e) Total Phosphorus (TP)

Phosphorus was studied to work out plant nutrient in freshwater of Kivu, because the nutrient often limits the expansion and biomass of algae in lakes and reservoirs. Thus, the sample is digested to simultaneously convert the ortho form of the polyphosphate and the organic phosphate. 50 mL graduated cylinders was wont to collect sample, reagents like phenolphthalein indicator, oil of vitriol solution, ammonium persulfate, crystal, and caustic soda, 1 N was tested in laboratory. Therefore, the subsequent equation was accustomed to determine the concentration of total phosphorus within the sample that was taken: mg/L P = mg/l from the curve x 50 ml divided by initial volume used (ml).

2.2.2. Determination of the population sample

The sample is defined as "a little of examples taken from and accustomed reflect some broader group"; it may be a subset from a larger population. The researchers employed the formula in sampling proportions to gather high-quality knowledge and assure that there will be no bias in the data collection (Yamane, 1986).

The sample was calculated using Yamane Taro formula: $n=\frac{N}{1+Ne^2}$

Where n = sample

N (Population)= *61115*

e: level of precision (error) = 0.1

We come up with; $n = \frac{61115}{1+61115 * 0.1^2} \approx 100$

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3.0 Result and Analysis

3.1 Demographic description of respondents

The current study involves different categories of respondents both male and female, with emphasis on the people who live in Gihundwe and Kamembe sectors. The study's scope is mainly in two sectors, thus respondents included urban settlers and executive secretaries of cells and sectors who were interviewed respectively.

Table 1: Distribution of respondents by categories

No	Category of respondents	Number of respondents	Percentage (%)
1	Population of Gihundwe sector	47	37.30
2	Population of Kamembe sector	53	42.06
3	Staffs of the cells	22	17.46
4	Staffs at the sector level	4	3.17
Total		126	100

Source: Primary data

3.2. Factors influencing Rusizi urban growth

This section is composed of results coming from respondents who filled questionnaires and those who were interviewed.

Table 2: Data from Gihundwe and Kamembe sectors urban dwellers

Statement	Strongly agree (5)	Agree (4)	Neither agree nor disagree (3)	Disagree (2)	Strongly disagree (1)
Development of settlement	30	48	3	7	0
Increase of population	25	50	1	12	0
Good climate	20	46	0	22	0
Development of trade	32	45	0	11	0
Development of transport and communication	28	39	3	17	1
Availability of educational and recreational facilities	16	57	2	13	0
Migration	38	35	0	15	0
Proximity to Democratic Republic of Congo (DRC)	40	40	0	8	0

Source: Primary source

Based on the Table 2, it is obvious that urban growth in Rusizi is due to different factors as it has been explained by settlers of Kamembe and Gihundwe sectors. Development of settlement was proved by 34% of the respondents who strongly agreed and 54.5% who just agreed corresponding to 88.5% of the total respondents, increase of population was accepted by 28% of respondents who strongly agreed and 62.5% of respondents who just agreed which correspond to 80.5% of all respondents. Good climate was also highlighted to be important factor for the growth of Rusizi urban area where 22.7% responds strongly agreed, 52.2% respondents agreed, corresponding to 75%. It was also obvious that 36%

respondents strongly agreed, 51% respondents agreed which correspond to 87% revealed that development of trade played a relevant role in the development of this city.

In addition, transport and communication has led to the growth of Rusizi town as 32% respondents strongly agreed, 44% respondents just agreed, corresponding to 76% of total respondents. Availability of educational and recreational facilities was also shown as important for this area to grow as 18% respondents strongly agreed, 65% respondents agreed which correspond to 83%. Furthermore, 43% respondents strongly agreed, 40% respondents agreed that migration had a vital role in the growth of Rusizi town. The study also recognized the role of proximity to Democratic Republic of Congo in the growth of this area as 45% respondents strongly agreed, 45% just agreed corresponding to 90% of all respondents.

Although, it was not mentioned on questionnaire, hospitality of people of Rusizi has been revealed to be one of the factors for the growth of Rusizi town as 5% of the respondents added it.

Moreover, 18 local leaders interviewed out of 26 corresponding to 69 % emphasized that Rusizi town has grown due to the factors given by population above. However, they have added other factors such as government policy, urban planning, and enforcement of laws to play a considerable role in the growth of this town.

Table 3: Human activities carried out along the coastline of lake Kivu.

Type of activity	Most common practiced	Moderately practiced	Least practiced
Agriculture	-	10	-
Fishing	25	-	-
Road and Water transport	5	-	-
Boat construction	-	-	3
Car wash	-	-	3
Tourism and recreation	14	-	-
Hotel operations	15	-	-

Source: Primary data

Based on the Table 3, respondents have ranked activities carried out along the coastline of lake Kivu as follow; fishing with 28%, hotel operations with 17% and tourism and recreation, and road and water transport with 5% as the most practiced activities. Agriculture with 11% was proved to be moderately practiced activities while boat construction with 3% and car wash with 3% were proved to be least practiced activities. However, although it was not mentioned on questionnaire that 9% respondents said that the construction of houses and hotels, as the activities carried out there, while 1% respondent said that lumbering activities are carried out along Kivu coastline.

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Table 4: Impacts of human activities on the coastline of lake Kivu.

Statement	Strongly agree (5)	Agree (4)	Neither agree nor disagree (3)	Disagree (2)	Strongly disagree (1)
Agriculture causes soil erosion which lead to water pollution by sediments and nutrients	13	31	0	40	4
Car wash causes water pollution	5	40	3	35	5
Hotels and domestic activities discharge sewages	7	35	2	41	3
Construction activities cause solid wastes which lead to sedimentation of lake kivu	4	50	0	28	6
Traditional methods of fishing causes depletion of fishes.	3	27	4	51	3
Boat building causes pollution of water	1	16	7	60	5
Water transport discharge oil spills which contaminates lake Kivu.	2	21	12	48	6
Settlement near lake Kivu leads to destruction of the aquatic ecosystem	8	33	3	39	4

Source: Primary source

Based on the Table.4. above, it was proved that human activities have number of effects on the coastline of lake Kivu. 15% respondents strongly agreed, 35% respondents agreed, corresponding to 50% that agriculture causes soil erosion which led to water pollution; 6% respondents strongly agreed, 45% just agreed, corresponding to 51% that car wash causes water pollution. In addition, hotels and domestic activities have been accused to discharge sewages which cause eutrophication by 8% of respondents who strongly agreed and 40% which correspond to 48%. Furthermore, 4.5% respondents strongly agreed, 56% agreed that construction activities caused solid wastes which lead to sedimentation of lake kivu; traditional methods of fishing used by fishermen in Rusizi have been revealed to cause depletion of fishes by 3% of respondents who strongly agreed and 31% respondents who agreed, corresponding to 34%. The study also showed that boat building causes intoxication of water as 1% responds strongly agreed and 18% respondents agreed which correspond to 19% of all respondents.

More so, the research showed that water transport discharge oil spills which contaminates lake Kivu, as it was proved by 2% respondents who strongly agreed and 24% respondents who just agreed, corresponding to 26%. The study also revealed that settlement near lake kivu leads to destruction of the aquatic ecosystem as 9% respondents strongly agreed and 37.5% just agreed which correspond to 46.5% of all respondents.

3.3 Laboratory results

This section is composed of experimental results of different physio-chemical parameters such as hydrogen potential (ph), total phosphate (TP), total nitrogen (TN), chemical oxygen demand (COD), and biological oxygen demand (BOD) taken from various areas of Rusizi including Kivu compound in Rugenge wetland, Budiki swamp, Gatandara river and

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Kadasomwa river. Wastewater was tested in the UNILAK laboratory, and the following results were obtained:

Table 5: Laboratory results

Parameter	Kivu compound	Budiki swamp	Gatandara river	Kadasomwa river	Unity	Methods	Rwanda standard limit of the parameter
PH	8.6	8.9	8.7	8.1	-	EPA 150.1	6.5-8.9
TP	0.21	0.31	0.25	0.24	mg/l	Hach 10209	≤ 0.31 mg/l
TN	13.5	14.3	28.9	11.2	mg/l	Hach 10072	30 mg/l
COD	96	128	108.8	144	mg/l	EPA 410.4	250 mg/l
BOD	336	448	380.8	504	Mg/l	EPA 410.4	50 mg/l

Source: Primary source

3.3.1 pH value

The study's findings demonstrated a 100% compliance with the Rwandan requirement at every site that was under observation. There were no significant differences among sites where samples were taken because the pH value observed was in the range of 5-9, which is a Rwandan standard of 6.5-8.9 according to the report on water quality management of 2020 (Gov, 2020). Thus, as all recorded pH values from Kivu compound, Budiki swamp, Gatandara river and Kadasomwa river were within the pH ranges (minimum and maximum) listed in Table 1 above. While the surface water was slightly basic as a result of air oxygen penetration combined with photosynthetic algae activity in surface water, water discharge was often slightly acidic due to oxygen depletion underground.

3.3.2 Total Phosphorus (TP)

The study's findings revealed that the overall amount of phosphorus was in complete conformity with the norm. Since all recorded values in all monitored sites were within the standard limit, there were no significant changes between the sites (see Table 5). Thus, as the results obtained are between 0.21mg/l and 0.31mg/l, they are in a good range because the TP standard limit is very strict with a limit value of ≤ 0.3 mg/l for good water status. Although, the total phosphorus of Kivu compound of 0.21mg/l is low compared to those of its inlet rivers including 0.31mg/l of Budiki swamp, 0.25mg/l of Gatandara river, and 0.24mg/l of Kadasomwa river, these rivers will continue to have significant effects on the coastline of lake kivu as they discharge their water in lake Kivu.

Since it assesses the number of domestic wastewaters, notably those containing detergents, industrial effluents, fertilizer, and run-off, TP detection is crucial for establishing the quality of surface water.

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3.3.3 Total Nitrogen (TN)

Results from this study showed a 100 % compliance of the total nitrogen (TN) in all monitoring sites were below the standard limit of 30 mg/l. Recorded concentrations were varying between 11.2 and 13.5 mg/l as shown in Table 1.

3.3.4 Chemical Oxygen Demand (COD)

The study's findings revealed that COD ranged from 96 to 144 mg/l. All monitoring locations had the results below the regulatory limit of 250 mg/l of COD, indicating complete compliance with the Rwandan standard.

3.3.5 Biological Oxygen Demand (BOD)

Laboratory results proved that Kivu compound discharges effluent with a BOD level of 336 mg/L, Budiki swamp discharges BOD of 448 mg/L, Gatandara river discharges 380.8 mg/L and Kadasomwa river 504 mg/L. Simply looking at the difference in concentration between the four areas, all regions have high concentration of BOD beyond the standard level of 50 mg/L. Thus, the great concentration of BOD has tremendous effects on aquatic biodiversity because it causes depletion of oxygen in coastline of lake Kivu which generate high stress to aquatic organisms, hence suffocation and death of aquatic life.

4.0 Discussion

Based on the Table 2, it is evident that there are various factors which led to growth of Rusizi urban area as they have been explained by settlers of Kamembe and Gihundwe sectors. They include development of settlement, increase of population, good climate of the region as they have been revealed by different respondents. In addition, trade has played a pivotal role in the development of the area, and transport facilities contributed a lot in the growth of Rusizi urban area. The result of the study also revealed that availability of social amenities such as educational and recreational were responsible for the growth of the area. All the above said factors clearly show that Rusizi urban area will continue to grow, in this regard Rusizi urban planners and local leaders have to do deep study on how the growth this region will hand in hand with mitigation measures for environmental sustainability.

Figure 2: Photo taken in Rusizi Distict, Gihundwe sector, at the place named Kacyangugu, Souce: https://www.kigalitoday.com/ubukungu/iterambere/Rusizi-Abayobozi-barasabwa-kunoza-imyubakire-y-umujyi

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This photo shown in (Figure 2) the view of Kacyangugu place before 2000 (left), and the current one (right). Comparatively, it is very obvious that many things were changed in terms of infrastructures, and this may consequently lead to people lifestyle change. In addition, the infrastructure has changed so much with road crossing the entire town and across the sectors, in Rusizi District. This well clarifies how the governments urban settlement plan, once implemented, results in various urban characteristics. In other words, specifically, here in Rusizi city, especially in Kamembe and Gihundwe sectors modern houses, well designed house, new urban spatial growth, increase of business area, increase of Rural- to Kamembe and Gihundwe migration are the consequences of on-going implementation of government city urban master plan. This matches well with what is incorporated in Rusizi Secondary city urban planning report, (Detailed Rusizi Secondary City Master Plan 2012), whereby housing, roads, zones of activities are planned (see the Appendix-photos 1-5).

Based on the Table 3, it is obvious that they are different anthropogenic activities carried out along the coastline of lake Kivu which have led to the modification of this environment. In this regard, different respondents mentioned activities such as fishing with 28%, hotel operations with 17% and tourism and recreation as the most practiced activities; agriculture with 11% and water transport with 5% were proved to be moderately practiced activities while boat construction with 3% and car wash with 3% were proved to be least practiced activities. However, the results of this study revealed that they have had tremendous impacts on the coastline of lake Kivu and root cause of the degradation of environment in this area.

Transport development in this district in its three forms (Road, air and water transports) are executed, which may make it special in receiving people from different place inside the country, and people from neighboring countries and far foreign countries. For instance, passengers from Kamembe airport are almost all hosted in Rusizi city and are from various places of the country, plus foreign countries. This goes hand in hand with the report stating that water transport also makes Rusizi city the core place of people from DRC and inside the country, due to the cross-border dynamics (www.socialscienceinaction.org).

Logically, this centripetal-like transport will consequently make many things change especially housing in terms hotels, lodges, restaurants, banks etc. In the same sense, schools and health facilities will be also built later one to solve the needs of newly settled people in Rusizi city, especially in Kamembe and Gihundwe sectors.

Figure 3: Photos showing transport in Rusizi city, Kamembe sector: road transport (left) and water transport (right), December 2020.

Based on the results presented in table 4, the following impacts were identified:

a. Soil erosion

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In this study,15% respondents strongly agreed, 35% respondents agreed that agriculture causes soil erosion which led to water pollution. This is because eroded soils from farmland near lake kivu contain leaves and wood debris, animal manure, fertilizers, pesticides and herbicides, thus when they are washed away by runoff and discharged into lake cause water pollution and sedimentation. By correlation this with high increase of Kivu compound discharges effluent with a BOD level of 336 mg/L, Budiki swamp discharges BOD of 448 mg/L, Gatandara river discharges 380.8 mg/L and Kadasomwa river 504 mg/Lon the coastline of lake Kivu, it is clear that agriculture pose a threat to the environment safety of the area.

In addition, based on the results presented in the Table 4, 4.5% respondents strongly agreed, 56% agreed that construction activities caused solid wastes which lead to sedimentation of lake Kivu. The study also revealed that settlement near lake kivu cause destruction of the aquatic ecosystem as 9% respondents strongly agreed and 37.5% just agreed. This is because the growth of Rusizi town accompanied with many construction including houses, hotels, roads among others have proved to be source of solid waste materials which are dumped in the rivers such as Budiki and Gatandara that empty in lake Kivu, hence causing sedimentation and pollution of lake.

b. Water pollution

According to Olapade, 2010, the sources of effluents in lake Kivu include herbicides and pesticides application by farmers around and near the lake; human and animal faeces, sewage, bathing, laundry, effluent from industries and mines majority of which are concentrated in the Democratic Republic of Congo; Oil and Metallic wastes from Mechanic Workshops (Car washing) and mineral releases from volcanic rocks (Olapade B. O., 2010).

This study revealed that 6% respondents strongly agreed, 45% just agreed that car wash causes water pollution. This is evidenced by different car washes found in Rusizi town generally and the one that was found near the border of Rusizi I. These have had severe impacts on coastline of lake Kivu including death of fish and degradation of water quality which threatens the lives of all aquatic organisms in the area because when people wash vehicles; soaps, dirty and oil washed from cars flow into lake while they contain chemicals like phosphates which removes oxygen from the water of the lake needed by every aquatic species to survive.

c. Eutrophication

According to Pratt (2003), the greater nutrient concentrations result in higher primary production and phosphorus is the main cause of eutrophication in aquatic ecosystems. Although, this study showed that the total phosphorus measured from different areas around the coastline of lake Kivu increased from 0.21-0.31mg/l which is the normal range, continuous monitoring of the water quality of the lake is needed. However, as results obtained from different respondents accused hotels and domestic activities done in Gihundwe and Kamembe sectorsto discharge sewages in the environment which cause eutrophication as 8% of respondents strongly agreed and 40% who just agreed which correspond to 48% of the total respondents.

This has a strong correlation with laboratory results which showed that discharges of effluents with a BOD level of 336 mg/L from Kivu compoud, Budiki swamp discharges BOD of 448 mg/L, Gatandara river discharges 380.8 mg/L and Kadasomwa river 504 mg/L which are high concentration of BOD beyond the standard level of 50 mg/L. Thus, this clarifies that effluents, sewages, wastewater discharge and urban storm water resulting from Rusizi urban growth have severe impacts on the environment in the region generally and specifically on the coastline of lake Kivu because the great concentration of BODlead to loss of biodiversity as it causes depletion of oxygen in coastline of lake Kivu which generate high stress to aquatic organisms, hence suffocation and death of aquatic life.This situation is very critical to the ecosystem of the coastline of lake Kivu because as the BOD will continue to increase its effects will be very devastating on biodiversity in the region.

d. Toxication of water

The result of this research revealed that 1% responds strongly agreed and 18% respondents just agreed that boat building causes toxication of water. This is because construction of ships in the region near

Project Peche very close to lake Kivu release different toxic substance like small metals and oil from batteries which contaminate the coastline of this lake. In addition, the study proved that water transport in lake Kivu discharge oil and chemical spills which contaminates lake Kivu, as it was said by 2% respondents who strongly agreed and 24% respondents who just agreed. This is also a typical fact showing that human activities destroy coastline of lake Kivu in Rusizi district in different ways.

Correlating results from respondents and those of the laboratory. Based on Table.1. showing laboratory results of samples taken in four regions of Rusizi town namely, Budiki swamp, Gatandara, kadasomwa and Kivu compound. The results of this study showed that some water quality parameters, including hydrogen potential (PH), total phosphate (TP), total nitrogen (TN), and chemical oxygen demand (COD), appeared to be generally within the acceptable range across the nation. However, parameters of biological oxygen demand (BOD) proved to be out of the national standard, it means beyond 50 mg/L. Thus, it was evident that there was significant difference between the obtained results and the standard level which means that wastewater discharges in these areas had polluted the coastline of lake Kivu which resulted in eutrophication, the death of fish and other living aquatics, hence destruction of the ecosystem as BOD continue to increase from wastewater discharged on coastline of lake Kivu.

In addition, previous research by other researchers revealed that human-induced variables such soil erosion from mining and agricultural activities, a lack of wastewater treatment facilities, and the use of pesticides and fertilizers have a major impact on Rwanda's water quality (SEKOMO, 2019). This research showed that urban growth also has significant effects on water quality in general and on coastline of lake Kivu specifically.

5.0 Conclusion

The study intended to analyze the impacts of Rusizi urban growth on kivu coastlines, and to come up with solutions to reduce such effects on the lake ecosystem. After gathering, interpreting, and analyzing the data, we come up to the following conclusion.

1. It is evident that factors such as development of settlement, increase of population, good climate, development of trade, development of transport and communication, availability of educational and recreational facilities, migration, and proximity to Democratic Republic of Congo (DRC) have been responsible for the growth of Rusizi urban center.
2. The study also proved that as this area continue to grow, human activities including agriculture, car wash, hotels, domestic activities, construction, fishing, boat building, water transport and settlement near lake kivu will increase. However, these have had great impacts on the environment particularly on Kivu coastline as it was the focus of this research.
3. The impacts of Rusizi urban growth on Kivu coastline including soil erosion resulting from agricultural activities carried out in Gihundwe and Rusizi Sectors, water pollution caused by leaves and wood debris, animal manure, fertilizers, pesticides and herbicides from soil erosion resulting from agriculture, soap and dirty from car wash, improper disposal of domestic wastes, all these led to destruction of biodiversity along the coastline of lake Kivu.

In addition, eutrophication caused by effluents, domestic sewages and wastewater discharge, and urban storm water resulting from Rusizi urban growth have severe impacts on the environment in the region generally and specifically on the coastline of lake Kivu because the great concentration of BOD has led to the loss biodiversity as they have been proved by results from respondents and laboratory experiments. There was also occurrence of sedimentation from remains of construction materials from construction, contamination of water of the lake caused by oil and chemical spills from ship building and water transport.

Although, different strategies such as collection and proper disposal of domestic wastes in different centers, afforestation, Rusizi master plan, sensitization of population and punishment of law breakers have been used to ensure the safety of environment in this district. This study revealed that Rusizi urban growth continue to have significant effects on the coastline of lake Kivu because of high

increase of population which is coupled with different human activities and unrespect of environmental law and construction law by some people of Gihundwe and Kamembe sectors.

Thus, important measures such enforcement of environmental laws in general and specifically regarding protection of lake Kivu coastline, promotion of green city, sustainable ways of construction, raising awareness of population on the importance of protecting the environment, sustainable agriculture, protection of the lake against pollution, punishment to law breakers, among others have to be established by government, institutions in charge of environmental protection like REMA, FONERWA, among others to ensure that risks of the destruction of the ecosystem on coastline of lake Kivu are handled.

6.0 Recommendation

Based on the above study findings and conclusion, various recommendations are made.

- To the government of Rwanda, I recommend that the ministry of environment in collaboration with local government to enforce laws regarding urban growth in Rusizi district.
- To Ministry of Lands and Forestry has to sensitize population on importance of green city by planting trees in urban area.
- To Ministry of Education, to increase research on sustainable way of developing urban center.
- To Rwanda Environment Management Authority, to monitor and punish people who fail to be compliance with environmental requirements.
- Local authorities of Rusizi district have to be very vigilant and accountable on the corruption cases that often occur in giving construction permits, monitoring different economic activities done in the area which have been proved to have detrimental effects on the environmental safety of lake Kivu coastline.
- To future researchers to do research on waste disposal in the area.

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