GSJ: Volume 11, Issue 3, March 2023, Online: ISSN 2320-9186
www.globalscientificjournal.com

ANALYSIS OF BENEFITS ASSOCIATED WITH WETLAND RESTORATION IN RWANDA

Jean de Dieu Nizeyimbabazi[1] and Abias Maniragaba[1]

[1]Faculty of Environmental Studies, University of Lay Adventists of Kigali (UNILAK), Kigali, Rwanda

Abstract: The objective of this study was to analyze benefits associated with wetland restoration case of Rugezi wetland located in the Northern Rwanda from 2000 to 2020. Secondary datasets of wetland restoration policies like removal of football playgrounds, human houses and farmlands and land uses management were used. The restoration benefits were specifically, change on water level and electricity production. These data were collected from the States Geological Survey (USGS Earth Explorer), National Institute of Statistics of Rwanda (NISR) and Burera district along with the Offices of Ntaruka and Mukungwa hydropower plants. The Extraction by Mask of the Spatial Analyst Tools in the Geographic Information System (GIS) built maps of land use and land cover over the study area. The Chart and Tables of Microsoft Excel revealed annual changes on water level and electricity production. Finally, the Pearson Correlation analysis analyzed the relationship between wetland restoration and its associated benefits. It was noted that wetland extended from 1,989.36 to 2,741.16 Ha in 2000 and 2020, respectively. Water level rose form 1,860 and 1,880 m^3/s between 2004 and 2020, respectively. From 2004 to 2020, the increased water level regenerated the hydropower from 20.09 to 32.02 MWH and from 53,028.70 up to 55,063.47 MWH at Ntaruka and Mukungwa Hydropower plants, respectively. The Pearson correlation analysis indicated the P values of 0.0072, 0.0072 for restoration with water change and Ntaruka electricity production along with 0.02 for restoration with Mukungwa electricity production. Similarly, the P value between wetland restoration and Rugezi hydropower generation was 0.03. All P values were lower than 0.05 and confirmed the statistically significance relationship between Rugezi wetland restoration and its benefits. The results of this study can facilitate policy makers to better understand ways of formulating and implementing further wetland restoration measures countrywide.

Keywords: Burera district, Hydropower plant, Rugezi wetland, Wetland restoration

1. Introduction

Wetlands provide valuable and countless functions to the environment including food production, maintenance of water quality, erosion control and reduction, flood control, provision of a natural system to process airborne pollutants [1]. They also serve as buffer zone between urban residential and industrial segments to improve the climate and physical impacts for example noise, control insect population, provide habitats for fish and other organisms and produce food, fiber and fodder to name a few [2, 3].

In Rwanda, abundant water resources are reflected by the existence of a network of wetlands and aquatic lands generally represented by lakes, rivers and wetlands across the country [4]. As recently provided by the 2008 wetlands inventory, there are 2860 wetlands, covering a total surface of 278, 536 ha, which corresponds to 10.6 percent of the country surface and 101 lakes covering a surface of 149,487 ha [5, 6]. Rugezi wetland is among the major wetland providing contributing to electricity generation Rwanda However; its degradation reduced the electricity production at Mukungwa and Ntaruka hydropower plants which delayed several economic development activities and community wellbeing as well [7].

In the middle of 2000, such scenario was recorded due to the removal of natural vegetation which reduced the ecosystem function, poor management of Rugezi wetland's upstream, degradation of the surrounding Rugezi-Bulera-Ruhondo watershed; poor station maintenance along with the recorded low rainfall which led to significant drop in depth of Lake Bulera and decreased water level [8, 9]. Some of the restoration policies included the 2003 Environment Policy, 2004 National Land Policy and 2005 Environment Law Land Law, agricultural and watershed management policies, erosion control structures; bamboo belt and Pennisetum grasses, planting of trees on the surrounding hillsides; distribution of improved cook stoves along with promoting integrated and environmentally farming practices; and income generating activities [10-12].

Recent studies which considered Rugezi wetland only evaluated changes on water level, water quality, agricultural production and electricity production trend. However, there is a gap on conducting a research which integrates different factors which caused wetland degradation and the restoration benefits which can help policy makers to ensure that expected changes are under record. Therefore, the uniqueness of this study was to assess the extent to which Rugezi wetland restoration polices contributed to the benefits under record from 2000 to 2020.

2. Materials and Methods

2.1 Description of study area

This study focused on the Rugezi Marsh located to the East of Lake Bulera on the border with Uganda at an altitude of 2,050 m [7]. The Rugezi extends over a surface of 67.35 km^2 and its catchment extends on approximately 190.70 km^2. The annual mean rainfall on the hillsides is 1,200 mm/year at Rwerere- Colline and the mean annual rainfall is 1,050 mm/year at Rwerere-Marais site. This swamp is embedded between mountains which dominate it by 400 m.

Rugezi wetland is a protected area and is also known as the Ruhengeri marsh and is one of the headwaters of the Nile situated in the Buberuka highlands of the Northern Province. This marsh has an altitude of 2,100 m developed from an accumulation of the organic materials within a quartzite rock trapping water depression [13]. Rugezi wetland is surrounded by eight by eight (8) administrative sectors namely Cyeru, Kivuye, Gatebe, Ruhunde, Butaro, Rwerere, Gicumbi, Miyove and Nyankenke (Figure 1). This human population pressure and degradation of uplands caused people to start cultivating in the Rugezi due to the reason that residents of these sectors who merely depend on agriculture (crop production and domestic animal rearing) in search for survival..

In addition, the wetland is made up of two valleys; the Rugezi valley with a length of 26 km and a width of 3 km and the Kamiranzovu valley with a length of 9 km and width of 2.5 km. The streams of the valleys meet at an altitude of 2,050 m and run into lake Bulera, about 200 m downstream [14].

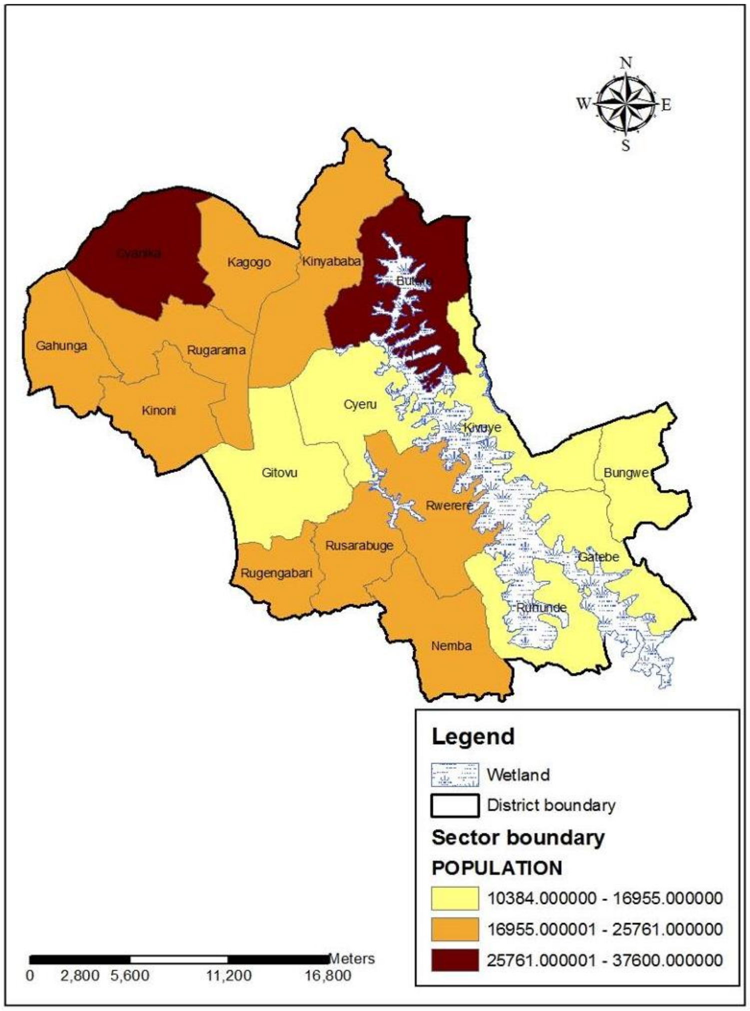


Figure 1: Map indicating the location of Rugezi wetland and its surrounding sectors

2.2 Data collection

For this study, total activities removed around the buffer zone of the wetland, land use and land cover change were considered as Rugezi wetland restoral measures. The employed dataset on the benefits associated with wetland restoration were changes on water level and electricity production. The datasets ranged from 2000 to 2020.

- The data on the recorded changes on water level and electricity production were generated by the Offices of Ntaruka and Mukungwa hydropower plants.
- The changes on population density around the wetland were collected from the National Institute of Statistics of Rwanda (NISR) and Burera district reports.

- Datasets on land use and land management were collected from the United States Geological Survey (USGS Earth Explorer).
- The shapefiles of the wetland and its surrounding sectors were collected from the National Institute of Statistics of Rwanda and Rwanda Water Board (RWRB).
- The data on the social and economic benefits of Rugezi wetland restoration among the communities were gathered from the Ranger Patrol Annual Reports of 2017, 2018, 2019 and 2020
- The data on some activities carried out to reduce erosion in the wetland buffer zone were also collected form the Ranger Patrol Annual Reports of 2017, 2018, 2019 and 2020, respectively.

2.3 Data analysis

The authors applied charts and tables of Microsoft Excel to indicate the number and types of activities expropriated within the wetland buffer zone. Furthermore, the Extraction by Mask of the Spatial Analyst Tools in the Geographic Information System (GIS) spatially distributed land use and land cover over the Rugezi wetland buffer zones for the period ranging from 2000 to 2020.

In addition, Tables and Charts form the Microsoft Excel software were used to reveal changes on socio-economic and environmental benefits of the wetland restoration measures. Finally, the Pearson Correlation Analysis helped to reveal the extent to which the initiated wetland restoration measures contributed to the recorded benefits. In order to successfully perform the Pearson Correlation analysis, the authors based on the fact that a p-value smaller than 0.05 indicates a statistically significant association (at 5 % level) and a p-value larger than 0.05 reveals no statistically significant association between two variables tested.

ISSN 2320-9186

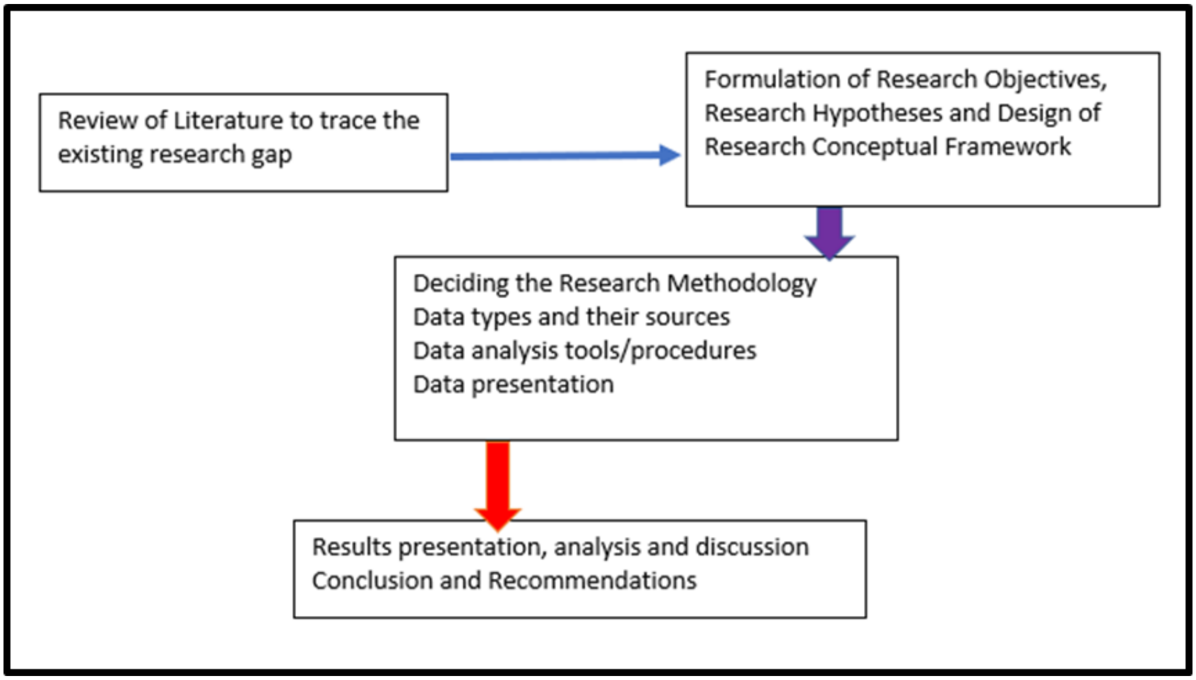


Figure 2: Proposed research methodological flowchart

3. Results

3.1 Rugezi wetland degradation activities

The results in Table 4.1 show that the majority of the recorded activities is related to farming (cropping and animal grazing, livestock shelter) practices which scored 463 action. The same Table 4.2 shows that 398 practices on forestation, tree cutting were recorded along with 135 human settlements, market and business houses, classroom were localized within the wetland and were attributed either directly or indirect to the wetland degradation.

Table 1: ***Some of the activities that degraded Rugezi wetland***

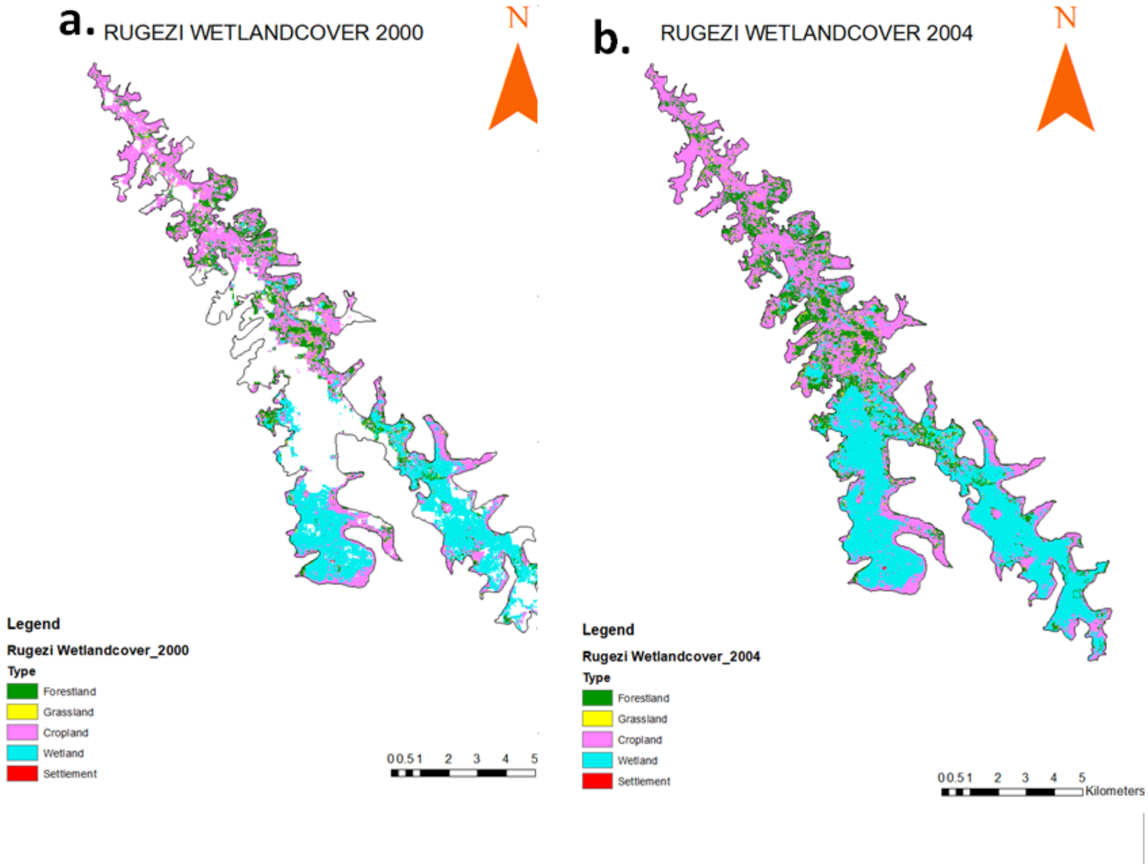
Activity/action	**Number**
Butchery/Slaughter house and Grinding machine	2
Football playground	20
Human settlements, market and business houses, classroom	135
Forest and tree cutting	398
Animal veterinary center	1
Brick making area, poaching and fishing, collection of fire wood	98

Farming (cropping and animal grazing, livestock shelter)	463
Total	**1,117**

The above wetland degradation activities affected the services which were normally offered by the Rugezi wetland mainly the generation of electricity which decreased due to water decrease. It is from this fact that the Government of Rwanda recognized this and set in place the wetland restoration activities. The following section details some of the activities initiated in order to protect the Rugezi wetland.

3.2 Wetland Restoration Activities

For the restoration, some policies were initiated among them, there are removal of some activities in the buffer zone of the wetland. With regard to the trend of the wetland degradation, the report of the Rwandan Wildlife Conservation Association (RWCA, 2020) shows that between 2017 and 2020, several illegal activities were still present in Rugezi marshland. The degradation trend decreased from 2020 onward compared to previous period. The results in Figure 3. a and b demonstrated that in 2000, the forestland over Rugezi wetland buffer zone was lower whereas the occupancy of cropland was dominantly high around the wetland. It can be noted that in the year 2000, the wetland was undergoing degradation which is the reason why the wetland cover decreased compared to agricultural land which overtook the wetland zone.



Figures 3.a and .b: Changes on land use at Rugezi buffer zones (2000-2004)

Moreover, the results in Figure 3.a demonstrated that the forestland over Rugezi wetland buffer zone was low whereas the occupancy of cropland was dominantly high around the wetland. However, as shown in Figures 3.b and 3.c, the area occupied by forestland, grassland as well as the wetland increased at a meaningful level. This is likely associated with the wetland restoration policies which were put in place in 2005.

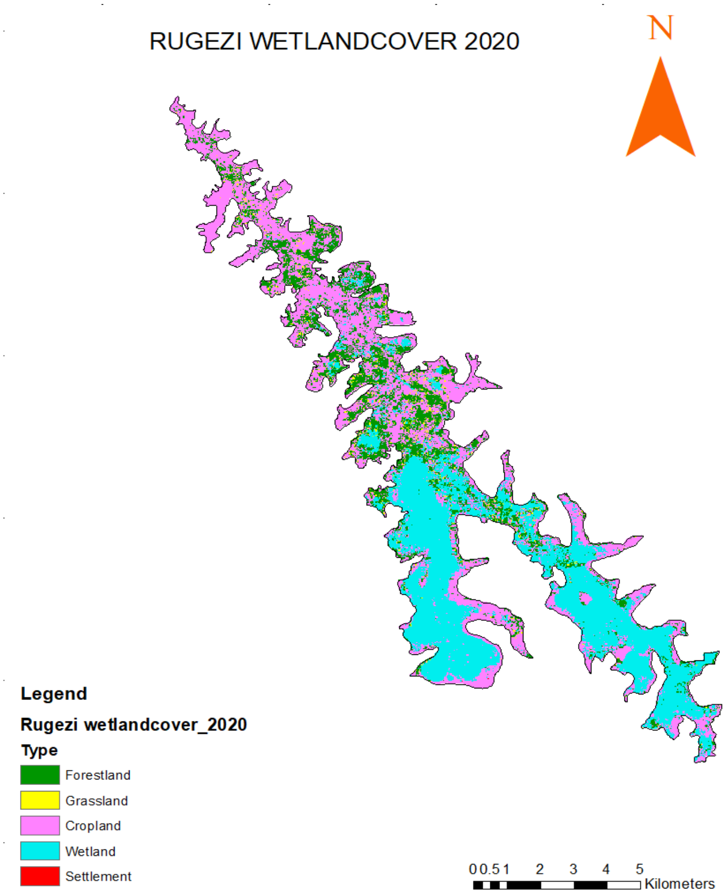


Figure 3.c: Changes on land use at Rugezi buffer zones in 2020

With reference to the results in Table 2, it can be noticed that between 2000 and 2004 little change on land use and land cover within the wetland buffer zone was recorded. However, in 2020, significant changes in terms of land use and land cover were noticed. For example, the wetland expanded from 1,989.36 to 2,741.16 Ha in 2000 and 2020, respectively. This certainly justifies the importance to the initiated wetland restoration measures. As shown in Table 1, the 192 activities which were removed from and/or close to Rugezi wetland contributed to changing its land use and its land cover features at 23.5338 percent between 2000 and 2020 (Table 2)

Table 2: Summary of land changes at Rugezi wetland buffer zone

	Land change in Ha per year				
LULC class	**2000**	**2004**	**2020**	**2004-2020 Total change (Ha)**	**Total change (%)**
Forestland	714.33	1,168.04	1,240.67	526.34	5.2634
Grassland	78.22	135.65	139.47	61.25	0.6125
Cropland	1,989.36	2,876.08	2,741.16	751.80	7.518

Wetland	1,597.53	2,551.91	2,613.17	1,015.64	10.1564
Settlement	2.17	3.31	0.52	-1.65	-0.0165
Total change (%)					**23.5338**

3.3 Benefits of Wetland Restoration

3.3.1 Changes on water level and Hydropower generation

The results in Table 3 indicated that that with regard to changes on the water level at Rugezi wetland, between 2004 and 2020, the water level was in the range of 1,860 and 1,880 m³/s. The increase in water level within the considered 17 years (2000-2020) was 24.45 m³/s and ranked 0.2445 percent of the recorded water level change (Table 3).

In addition, the production of electricity considered two hydropower stations namely Mukungwa and Ntaruka. It was noticed that electricity production at Ntaruka hydropower did not considerably increase. The production rose from 20.09 to 32.02 MWH in 2000 to 2020, respectively. However, for the Mukungwa Hydropower, a significant change in terms of electricity was registered. The electricity production augmented from 53,028.70 MWH in 2000 up to 55,063.47 MWH in 2020 which was estimated to be 20.3477 percent of change within the period ranging between 2004 and 2020 (Table 3).

Table 3: Changes on water level and hydropower production

		Electricity production Hydropower plant (MWH)	
Year	**Lake water level change (m³/s)**	**Ntaruka**	**Mukungwa**
2004	1,860.25	20.09	53,028.70
2005	1,859.84	14.56	39,994
2006	1,861.85	15.35	22,850.30
2007	1,861.13	5.68	18,103
2008	1,861.09	2.45	44,146.50
2009	1,862.4	1.16	63,119.60
2010	1,862.7	15.09	67,163.52
2011	1,862.38	29.4	68,460.05
2012	1,863	29.01	77,928.79
2013	1,863.53	29.88	71,468.15
2014	-----------	----	70,157.10

2015	1,863.68	30.04	77,26.47
2016	1,863.71	30.78	46,278.53
2017	1,87.04	30.15	55,988.77
2018	1,870.63	30.38	53,650.22
2019	1,871.32	31.88	36,115.58
2020	1,884.74	32.02	55,063.47
2000-2020 Total change	24.45	11.93	2,034.77
Total change (%)	**0.2445**	**0.1193**	**20.3477**

Source: Mukungwa and Ntaruka Hydropower plants, (2021)

Regarding the electricity production at the Rugezi hydropower plant, the results in Figure 5 demonstrated that in 2017, the electricity increased from 1,507 to 11,958 MWH in 2017. The production finally increased up to 14,307 MWH in 2020. Thus, a significant increase was recorded at Rugezi hydropower plant after the Rugezi wetland restoration.

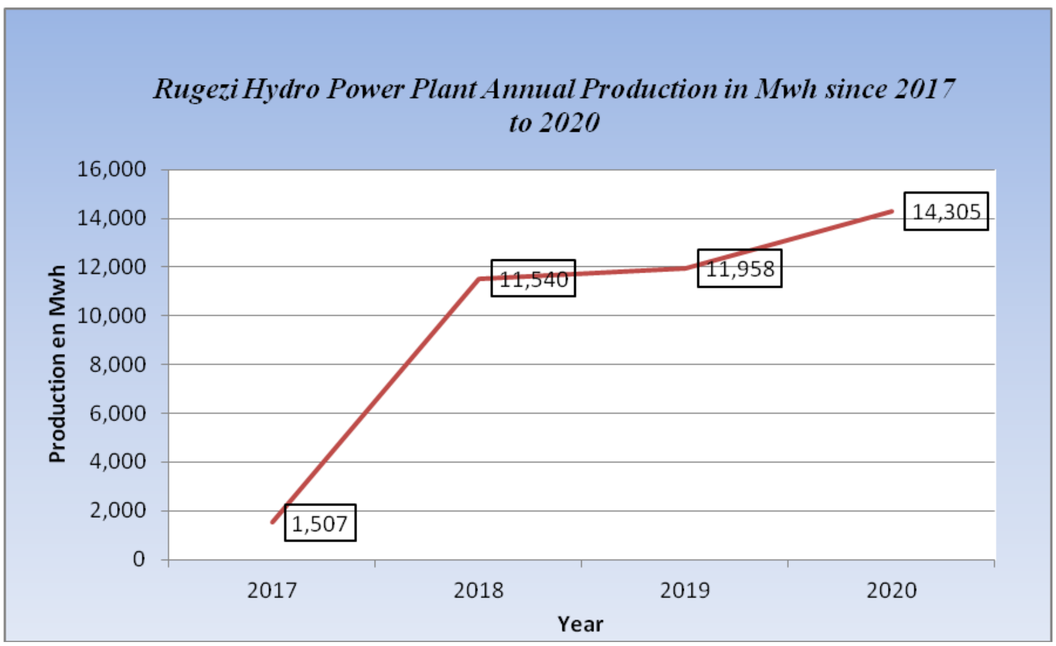


Figure 5: Rugezi Hydropower plant annual production

3.3.2 Socio-economic benefits

The results in Table 3 details some of the socio-economic benefits recorded among the Rugezi wetland surrounding communities where 1,205 health insurances are payed for the communities surrounding the Rugezi wetland as the results of its restoration activities. In addition, Rwanda Wildlife Conservation Association provides both temporal (939) and permanent (37) jobs to people around the wetland. This serves on two folds by increasing the socio-economic livelihoods of people but also maintaining the wetland conservation efforts.

*Table 3: **Rugezi wetland socio-economic restoration benefits***

No	Benefits	Number	Quantity (Kg)
1	Donation of pigs	10	
2	Agricultural production		
	Cabbage		1,850
	Carrots		120
	Betteraves		60
	Beans		40
	Maize		20
3	Health insurance payment	1,205	
4	Houses renovated	21	
5	Rainwater harvesting tools installed	21	
6	Mattress		
7	Bikes given to rangers for the conservation surveillance	98	
8	Temporal jobs by Rwanda Wildlife Conservation Association	939	
9	Full time jobs by Rwanda Wildlife Conservation Association	37	
	Sewing groups trained	16	

3.3.3 Environmental benefits

The results in Table 4 show that among the actions taken to reduce the degradation of Rugezi wetland, 28,000 fodder cuttings were distributed to reduce grazing in the wetland. In addition, 61,348 people attended the wetland conservation events organized by Rangers around the Rugezi wetland.

Table 4: Env***ironmental actions undertaken***

No	Actions	Number
1	Families that signed Rugezi conservation agreements	68
2	Cooperatives that signed Rugezi conservation agreements	368
3	Fodder cuttings distributed to reduce grazing in the wetland	28,000
4	Engagement of women-based conservation groups	147
5	**Rugezi water conservation efforts**	
	Engine for watering the crops	1
	Water pipes	3
	Wetland conservation awareness/training/workshop (attendants)	391
6	Conservation events organized by Rangers	516

7	Attendants to conservation events organized by Rangers	61,348
8	Students provided with conservation trainings	9,729

3.4 Effect of wetland restoration on associated benefits

Finally, in order to assess the extent to which the initiated Rugezi wetland restoration activities contributed to the recorded several benefits, the authors performed a correlation analysis. This enabled the authors to obtain a statistical significance between both tested research independent (restoration activities) and dependent (restoration benefits) variables.

Table 5**: Correlation analysis between restoration associated benefits**

		Restoration activities	Restoration benefits
Restoration activities	Pearson Correlation	1	.0021
	Sig. (2-tailed)		.341
	N	3	3
Restoration benefits	Pearson Correlation	.0021	1
	Sig. (2-tailed)	.341	
	N	3	3

The obtained P value of 0.021 is lower than 0.05 and positive, which expresses a very high/large extent of the independent variable contribution to independent variable. Therefore, based on the calculated P value (0.061) which is high, it is concluded that the restoration activities of Rugezi wetland contributed to several benefits.

4. Discussion

The concern on durable management of natural resources mainly land and water is attracting almost everyone's attention. This mainly results from the reason that both resources are sources of human livelihoods in term of agriculture, energy sources, mining and transport, etc [15, 16]. In Rwanda too, sustainable management of natural resources remains a core development goal towards socio-economic transformation among residents [17].

In Rwanda, the major challenges to sustainable management of natural resources include not limited to the rapidly growing demographic patterns, rising demands of intensified socio-economic development, unsustainable and inappropriate land-use practices, along with uncertainties created by climate change [6, 18]. This affected the Rugezi wetland which in turn, led to reduction of electricity production in different parts of the country since both Ntaruka and Mukungwa hydropower plants lacked sufficient water to use in electricity production [19].

However, restoration of Rugezi wetland after the year 2000 revealed positive effect in terms of land use and land management. This fact results from the reason that the level of water increased, the land under wetland expanded and the electricity generation recorded growing trend. In addition, there are jobs (both temporal and full time), health insurance and mattress and pigs delivered to communities near the wetland. This was similarly approved by the results of this study where more than 2,000 activities were stopped/reduced form the buffer zones of the Rugezi wetland contributed significantly to its restoration [20, 21].

As indicated in Figures 4.1, 4.2 and 4.3, the land uses mainly wetland comparatively expanded from 1597.53 to 2613.17 Ha in 2000 and 2020, respectively (the considered study period). This restoration was later certified by the water level increase as well as augmented electrify production at Ntaruka and particularly at Mukungwa hydropower plant (Table 4.3 and Figure 4.6). In addition, the results (see Table 4.4) on the socio-economic benefits show that 1,205 health insurances, temporal (939) and permanent (37) jobs were offered to people around the wetland. For the environmental benefits (as shown in Table 4.5), 28,000 fodder cuttings were distributed to reduce grazing in the wetland. In addition, 61,348 people attended the wetland conservation events organized by Rangers around the Rugezi wetland.

Recent studies which considered Rugezi wetland, mainly emphasized on its degradation (causes and impact) and a few of them revealed the benefits of the restoration policies. However, based on the researcher's best of knowledge no study which tried to reveal the types of wetland restoration initiatives which were executed, the benefits recorded and their statistical relationship. This study was conducted in completion of this gap and the results as shown in Tables 4.4. and 4.5 revealed that the restoration of Rugezi wetland significantly contributed to several socio-economic and environmental benefits.

5. Conclusion

This study tested the extent to which Rugezi wetland restoration contributed to the recorded benefits mainly change on the wetland water level and hydropower generation form three hydropower production plants (Rugezi, Ntaruka and Mukungwa) whose water source is Rugezi wetland. The authors employed secondary datasets on wetland restoration policies initiated (types and number), water level change, electricity production of both hydropower plants. The research findings confirmed that restoration of Rugezi wetland has significantly contributed to the increasing it water level and hydropower generation. Since the agricultural expansion and other human activities were the major factor of Rugezi wetland degradation, the local communities are recommended to ensure the respect of the provided buffer zones of the wetland. Policy makers are recommended to annually conduct and land use and land cover assessment at the buffer zones of the wetland and share the results with local communities to ensure that the policies are supported form grassroots level. Future studies can evaluate the extent to which Rugezi wetland surrounding communities are acting in its sustainable management.

Acknowledgements

The authors thank all data providers which contributed to the successful completion of this study.

References

[1] Euliss Jr NH, Mushet DM, Newton WE, Otto CR, Nelson RD, LaBaugh JW, et al. Placing prairie pothole wetlands along spatial and temporal continua to improve integration of wetland function in ecological investigations. Journal of Hydrology 2014;513:490-503.
[2] Brandis K, Bino G, Spencer J, Ramp D, Kingsford R. Decline in colonial waterbird breeding highlights loss of Ramsar wetland function. Biological conservation 2018;225:22-30.
[3] Bazzuri ME, Gabellone NA, Solari LC. Zooplankton-population dynamics in the Salado-River basin (Buenos Aires, Argentina) in relation to hydraulic works and resulting wetland function. Aquatic Sciences 2020;82:1-18.
[4] Mbabazi SS. Wetlands management and conservation in Rwanda. Case Study: Gikondo wetland. South Africa: Witwatersrand; 2010.
[5] Ndayisaba F, Guo H, Isabwe A, Bao A, Nahayo L, Khan G, et al. Inter-Annual Vegetation Changes in Response to Climate Variability in Rwanda. Journal of Environmental Protection 2017;8:464.
[6] Sinsch U, Lümkemann K, Rosar K, Schwarz C, Dehling M. Acoustic niche partitioning in an anuran community inhabiting an Afromontane wetland (Butare, Rwanda). African Zoology 2012;47:60-73.
[7] Grundling P-L, Grootjans, A.P and 4Linström, A. Rugezi Marsh, a high altitude tropical peatland in Rwanda Researchgate 2018.
[8] Hove H, Parry J, Lujara N. Maintenance of hydropower potential in Rwanda through ecosystem restoration. World Resources Report, Washington DC 2010.
[9] Kazoora C, Hagwirineza JB. The relationship between Bio-Physical Factors and Power Generation at Ntaruka, Rwanda and implications for revenue generation. 2011.

[10] Bimenyimana S, Asemota GN, Li L. The state of the power sector in rwanda: a progressive sector with ambitious targets. Frontiers in Energy Research 2018;6:68.
[11] Kabera T. Environmental impact assessment in higher education institutions in East Africa: the case of Rwanda. Environmental Science and Pollution Research 2017;24:7852-64.
[12] Rubimbura VM, Idukunda C, Nsanzabaganwa J, Yambabariye E, Nahayo L, Maniragaba A. Impact of Community Behavior Change on Environmental Protection in Rwanda. Journal of Environment Protection and Sustainable Development 2020;6:11-5.
[13] Rwanda v. Rugezi Marsh Rwanda. 2019.
[14] Nzabonantuma L. Wetland modeling to support restoration planning: the case study of Rugezi, Rwanda: Unesco-IHE; 2011.
[15] Gonzalez FR, Raval S, Taplin R, Timms W, Hitch M. Evaluation of Impact of Potential Extreme Rainfall Events on Mining in Peru. Natural Resources Research 2018:1-16.
[16] McCarthy N, Dutilly-Diane C, Drabo B. Cooperation, collective action and natural resources management in Burkina Faso. Agricultural Systems 2004;82:233-55.
[17] de Dieu Uwisengeyimana J, Teke A, Ibrikci T. Current overview of renewable energy resources in Rwanda. Journal of Energy and Natural Resources 2017;5:92-7.
[18] Bosco NJ, Ildephonse M, Alexandre N. Agriculture and Food Security in Gicumbi District, Northern Province of Rwanda. International Academic Journal of Social Sciences 2018;5:154-68.
[19] Grundling P-L, Grootjans A, Linström A. Rugezi Marsh: A High Altitude Tropical Peatland in Rwanda. 2018.
[20] Kabanguka N. Participatory threat assessment for conservation planning at Rugezi, Rwanda. African cranes, wetlands and communities 2013.
[21] Ndomba PM, Magoma D, Mtalo FW, Nobert J. Application of SWAT in Natural Wetland Catchments. A Case of Rugezi Catchment in Rwanda. Nile Basin Water Science & Engineering Journal 2010;3.