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Impact of Soil Erosion on Water Quality in Mwogo River in Huye District, Rwanda

Jean Adolphe Nkezabera*, Narcisse Hakizimana, Eric Maniraho, Monique Buteto, Abias Maniragaba

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

Abstract

Human activities, land forms and climate change made soil erosion challenges exists worldwide particularly in Rwanda as a big issue. Anthropogenic forces modify the feature landscape that caused significant soil erosion that has negative impact on surface water bodies. This study was conducted in order to identify most source of sediments to specify proper areas to government projects in Mwogo River protection in Nyamagabe and Huye Districts. Three sample sites with three parameters per site were taken by purposive method then evaluated through, Statistical Package for Social Sciences (SPSS). The results shown that Total Suspended Solids (TSS) and Turbidity were out of the acceptable range and Hydrogen potential (pH) was in acceptable range for natural potable water standards where the mean value on sites were PH 7.11, turbidity 4,301.33 NTU and TSS 1,327.66 mg/L. The short rainy season of 2020 and short dry season 2019 had very high correlation and significant impact on water quality where, $r = 0.999$ in range of $0.75 \leq r < 1$; very high and p value= 0.021; $\alpha=0.05$ (p value<α) meant that soil erosion had significant impact in Mwogo River in succession years. The sources of sediments had different source and different in concentration, the study shown that Huye district was more polluter but dominantly in Rusuli marshland in Huye district with turbidity 6880 NTU and TSS 2280 mg/L turbidity 5080 NTU and TSS 1190 mg/L at outlet of Huye district than turbidity 944 NTU and TSS 513 mg/L at outlet of Nyamagabe district from soil erosion impacts. The results shown that development was not proportion to environmental protection leads to deterioration of Mwogo water body, which indicated the requirement of strengthening water resource management measures through restoration of wetland and watershed by land cover, buffer zone promotion and runoff decrease rate powerfully in Huye district.

Keywords

Soil Erosion, Water Quality, Mwogo River, Huye District

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1. Introduction

Worldwide natural resources incessant degraded lead to finite of such resources included water, which is crucial to human, socio-economic development and between biotic in ecological functions for life sustainability in the world. Though, water can also source of harm to humans, plants and animals as well as to the social- economic activities as a result of disasters ascending by soil erosion, landslide, water borne diseases and floods [5].

The surface water is the natural water of the earth that degraded by natural and anthropogenic factors. Through soil

* Corresponding author
E-mail address: nkezaberaa@gmail.com (J. A. Nkezabera)

erosion that occurred naturally but accelerated by anthropogenic activities via wind and water erosion degrades the arable land, causing the soil to deteriorate that affects water from debris composed by physical and chemical toxic that harmed water body with respect to water quality damage. Soil erosion has different types that affect water quality; Sheet erosion, Rill erosion, Ephemeral erosion and Gully erosion [4].

Soil erosion affects water quality through the soil particles from the surface by rain water, runoff, snowmelt and irrigation. Predominantly, rain water in the form of runoff is the main cause of water erosion that deposing the eroded materials at the lower landscape positions and in aquatic systems [3]. The soil erosion estimated that 35.9 Pg. per year of soil eroded between 2001 and 2012 indicate that likely overall escalation in global soil erosion driven by cropland development. The highest intensifications are in sub-Saharan Africa, South America and southeast Asia [1].

The suspended sediments in Rwanda and further areas in the Nile Basin have been severely swelling in water bodies since the 1990s [8]. Therefore, suspended sediments can cause the presence of turbidity through clay, silt, sand, inorganic materials and organic matter for instance plankton one or both algae [11]. The hydrous erosion degraded the natural environment that distresses a big ration of arable lands that reduces the capacity of feed 40,000 people per year and sources of annual losses of 15,000,000 tons of soil, because of poor management of soils, estimated at 945,200 tons of organic materials for the whole country [13].

The mostly, soil erosion had impact to water quality in Rwanda country that caused a problem of sedimentation and siltation of surface water bodies [10] from landscape of the country characterized by hills and valleys influenced by cultivating on slope lands or vegetation alteration caused by a focus on domesticated animals feeds, resulting to sediment settle down on streambeds and replenishes the gaps below stones [9].

The sediments composed by different chemical compounds such as aluminium and iron found in various forms. As with Al, it is released into water from sediments via remobilization processes at pH less than 6 [7]. Aluminium naturally occurs as bauxite, the mobilization of aluminium in soluble forms from the soil to the aquatic ecosystem is an essential consequence of acidification of streams and lakes. The pH and concentration of inorganic aluminium are the significant factors for toxicity in acid waters [12].

Rwanda as developing country, it has different sectors to be developed for sustainable way such as agriculture, transport, energy, industry and mining sectors that has reflected to negative impacts of environment pollution particularly, on water quality. The EDPRS distinguishes the central role of water in economic development, declaring that: "above 80% of the diseases that affect Rwandans are waterborne; thus availability of safe water is a precondition for refining environmental and personal health [5].

Economic activity around Mwogo watershed is facing a problem of ecosystem degradation due to soil erosion and inappropriate management activities causing siltation of water. The population living nearby Mwogo watershed are greatly depending on forests as a core source of energy: 96.8% of households use firewood for cooking, 2.6% of households use charcoal, only 0.4% of households use crop waste and 0.2% use other primary source. Cultivation of vegetables, beans, maize and also public infrastructures like cultivated land, bridges and roads situated in Mwogo wetland [2].

Mwogo River is dominated by sediments in their sub catchment in both the composite along within each sample through Jan and April in specific areas of the headwaters, and therefore the result advocates severe confined disturbances in these areas. The composite values in 2016 indicate that the geological unit was the main contributor in Mwogo, on rate between 18 to 60% and is dominantly in Nyamagabe district (Cyanika, Gasaka sectors) and Huye district (Rwaniro, Kigoma, Simbi, Ruhashya, Mbazi sectors) [9].

The findings from the study of the Rwanda Water and Forestry Authority exposed that the parameters of water quality in Rwanda country water bodies were mostly in the acceptable range and others were almost permanently out of acceptance range for natural potable water for instance, Total Suspended Solids (TSS) and Turbidity parameters included water quality of Mwogo River [10]. The focus parameters in this study of impact of soil erosion on water quality in Mwogo River were the total suspended solids (TSS), turbidity and potential in hydrogen (PH) to identify most source of sediments in two districts in Mwogo River as suspended parameters to soil erosion from outlets of Nyamagabe to Huye Districts.

2. Materials and Methods

2.1. Description of Study Area

Mwogo upsurges in forested country in southern Rwanda to the east of the divide. It has its bases in the Kitabi sector of the Nyamagabe district. It turns eastward past between Kigomo, Maraba and Simbi sectors, across Rwaniro sector at Huye district. It turns in a northeast direction through the western part of this district, inflowing Nyanza district in pathway it joined with Gihimbi River, Rukarara River and Mbirurume River to form Nyabarongo River, which continues northward.

The latitude of Huye, Rwanda is -2.586166, and the longitude is 29.689026. Huye district is situated in Rwanda country as one 30 Districts, it geographical location through the GPS coordinates is 2° 35' 10.1976" S and 29° 41' 20.4936" E. The Rwanda relief is hilly and mountainous with an altitude ranging between 900 m and 4,507 m. Mwogo river as study area located at Huye district in central plateau. The central plateau presents a relief of hills with an altitude extending between 1500 m and 2000 m.

Mwogo river is located in the East of the Congo Nile Ridge there is the Nile basin which covers 67% of the National territory and drains 90% of Rwandan waters by two main 15 environmental Profile of Rwanda rivers namely Nyabarongo and Akagera. The latter is the central affluent of Lake Victoria with an average outflow of 256 m3 /s at Rusumo station and thus measured as the source of the Nile [13]. Rainfall is plentiful while it has some irregularities. Winds are generally around 1 to 3 m/s and the average of rainfall is extending between 1150 and 1280 mm at Huye district. Rainfall is less irregular, and occasionally bases periods of drought with four seasons, two are wet and the other two are dry [6].

The central plateau covers the regions of south and south east where Mwogo river crossways. The soil types are hill Ferro soils and valley Histosoil. The slopes of hills are disposed to erosion notably in the case of clay sandy or gravely soils.

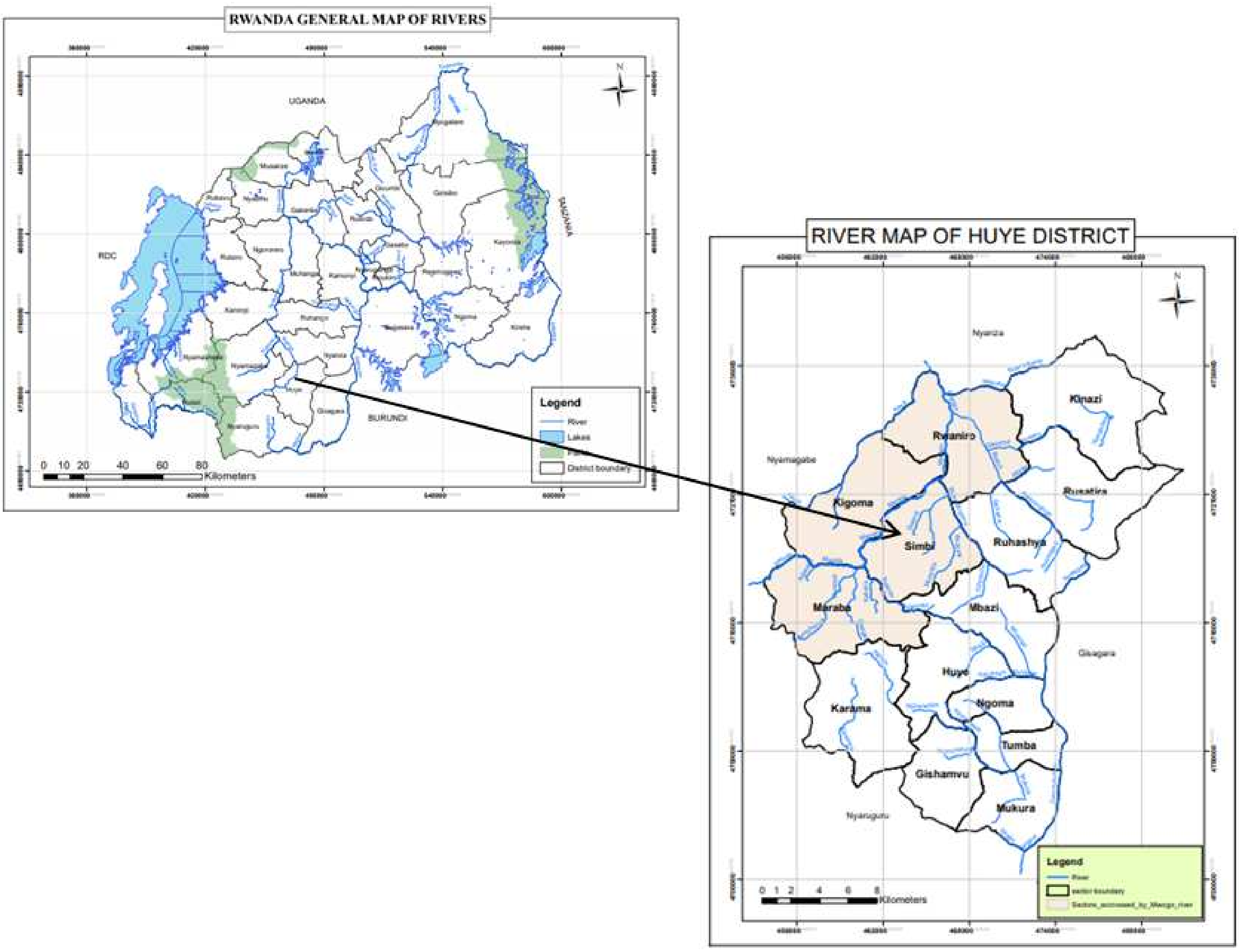

Figure 1. (a) Location of Mwogo river in Rwanda map. (b) Mwogo river across Huye district.

2.2. The Sample Points Sites in Mwogo River

A total number was three (3) sample points sites were selected from Mwogo river. The foundation for choosing these sites was to ensure representation the situation of river either in Nyamagabe or Huye districts during the study action.

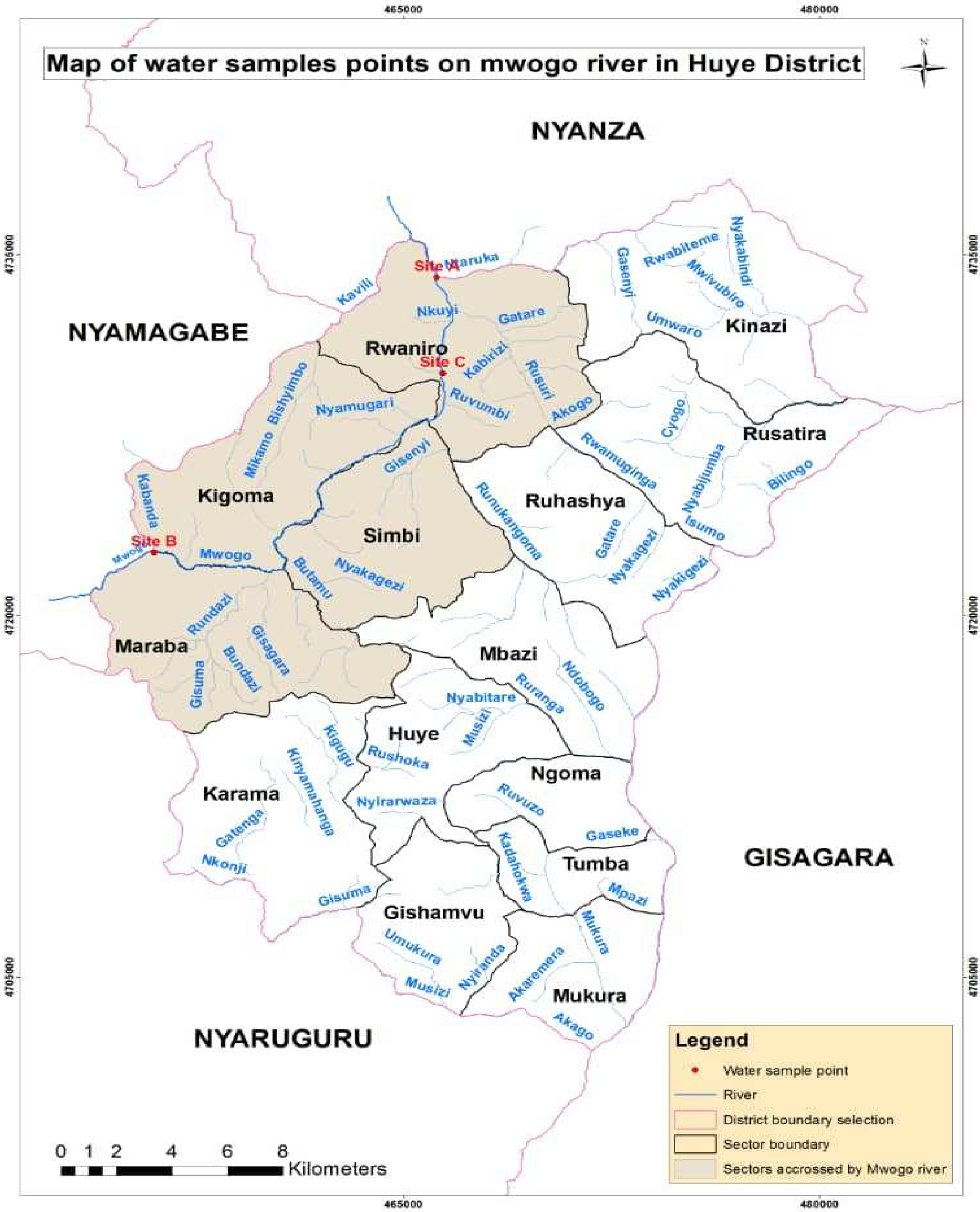

Figure 2. Water Quality monitoring sampling sites in Huye district on Mwogo river.

Site A: outlet of Mwogo river from Huye to Nyanza districts.
Site B: outlet of Mwogo river from Nyamagabe to Huye districts.
Site C: Mwogo River, feature land use (Rusuli marshland) in Huye district.

Figure 3. Mwogo River in short rainy (December) 2020. Source: Author.

2.3. Data Collection and Analysis

The main source of data was the samples from Mwogo river and concluded using secondary data from literature review. The selection of sampling sites was conducted through purposive non- random sampling method in Mwogo river in three separate sites, sampling was directed by means of the upstream to downstream method with respect watershed boundaries in Huye district aside Mwogo river by handheld calibrated. The samples were taken in one meter from bankside of river to avoid floating debris on the top.

The samples taken on the 16th December 2020 and laboratory analysis take place on 17th December 2020, where the results present the short rainy season 2020. The study outcomes have been deliberated basing on the standards of potable water (FDEAS 12:2018), baseline data collected by Rwanda water and forestry authority and Discharged domestic wastewater (FDRS 110: 2017) to Total Suspended Solids parameter. The data obtained was subjected to analysis through Microsoft excel and SPSS using T-test analysis on set of three (3) parameters; total suspended solids, turbidity and pH on each sampling site.

3. Results

3.1. The Variation of Parameters in Mwogo River

Table 1. Samples coordinate and water quality results.

Sites December 2020	sample coordinate by ITRF projection		PH	TSS mg/l	Turbidity NTU
	Y	X			
Site A	4734041	466207	7.0	1190	5080
Site B	4722629	456020	7.14	513	944
Site C	4730061	466428	7.2	2280	6880

The result in table 1 shown that Rusuli marshland in Huye district (Site C) had more source of soil sediments followed by outlet of Huye district (Site A) and outlet Nyamagabe district (Site B).

3.2. Statistical Analysis of River Data

3.2.1. The Correlation Between Soil Erosion and Water Quality in Mwogo River

The results obtained from sample sites was tested for any correlation between PH, Turbidity, TSS and both seasons with standards. In study, the parameters of PH, TSS and Turbidity indicated positive correlation which was strongly due to soil erosion. Pearson's correlation coefficient (r) were positive correlation, that indicated the impact of soil erosion influenced both parameters rise or decline together, while negative correlation shown how the impact of soil erosion impaired one parameters to increase and the others decrease.

The decisions on correlation of soil erosion on water quality was based on data analysis of the Pearson correlation coefficient “r”;

r=1; perfect

$0.75 \leq r < 1$; very high

$0.50 \leq r < 0.75$; high

$0.25 \leq r < 0.50$; low

$0 < r < 0.25$; very low

r=0; no correlation

Hence, Ho is accepted at P value> Alpha” α “

Ho: Soil erosion had no significant change on Mwogo River water quality.

H1: soil erosion had significant change on Mwogo River water quality.

Table 2. Pearson correlation coefficient between seasons.

		PI	PII	mean value	Standard
PI	Pearson Correlation	1	.935	.923	.589
	Sig. (2-tailed)		.232	.252	.599
	N	3	3	3	3
PII	Pearson Correlation	.935	1	.999*	.263
	Sig. (2-tailed)	.232		.021	.831
	N	3	3	3	3
mean value	Pearson Correlation	.923	.999*	1	.232
	Sig. (2-tailed)	.252	.021		.851
	N	3	3	3	3
Standard	Pearson Correlation	.589	.263	.232	1
	Sig. (2-tailed)	.599	.831	.851	
	N	3	3	3	3

*. Correlation is significant at the 0.05 level (2-tailed).

3.2.2. Interpretation of Impact of Soil Erosion on Water Quality

The table 1 indicated that, sources of sediments had different source and different in concentration, the study shown that Huye district was more polluter with turbidity 5080 NTU and TSS 1190 mg/L than from Nyamagabe district with turbidity 944 NTU and TSS 513 mg/L corresponded by site B from rain fed agriculture, sand mining and soil type with unprotected land accelerated by natural factors such as rainfall and climate condition in southern that reducing soil strength to resist on soil erosion.

Table 2 of Pearson correlation coefficient between seasons shown the seasonal variation of water quality of Mwogo River that sediments increased in succession years shown by the value between 2020 and 2019 had very high correlation and significant impact on water quality where, r= 0.999 in range of $0.75 \leq r < 1$; very high and p value= 0.021; α=0.05 (p value<α) meant that soil erosion had significant impact in Mwogo River in December 2020 then Ho is rejected. December 2020 and November 2018 r= 0.923 in range of $0.75 \leq r < 1$; very high correlation and insignificant impact of soil erosion where p value=0.252; α=0.05 (p value>α) meant that soil erosion in short rainy seasons had affected water quality insignificantly.

4. Discussions

The study was conducted in Huye district where there was a problem of Mwogo water pollution caused by soil erosion. the main objective was to analyse the impact of soil erosion in Mwogo river in Huye district. The values of the pH on the sites had no impair to river through remobilization process of aluminium ion and iron ion that affect aquatic fauna life system where remobilization processes happening at pH less than 6 [7]. The Turbidity values on sites meant that Mwogo water suspended to pathogens and with higher treatment cost through, Failure to meet turbidity targets for filtered water can indicate the possible presence of pathogens in drinking-water, and increased turbidity in distribution systems can represent detachment of biofilms and oxide scales or entry of external sources of contamination [14]. The total suspended solids values on sites indicated that Mwogo river at rainy season the flora system had injury caused by suspended sediment loadings on streams may affect stream faunas in several ways. High suspension levels may congest the food filtering or trapping apparatus of stream insects. Deposits of sediment can coat stone surfaces, both reducing the available food supply and eliminating attachment points for those animals such as larval blackflies which need to anchor themselves to the substrate [15].

5. Conclusion

The high rainfalls and fast-moving winds that fall in spring and early summer causing soil erosion in areas where is a lack of vegetation. Moreover, erosion is facilitated by the fact where the annual precipitation distribution is very irregular [16]. The findings from study shown that soil erosion has impact in Mwogo river. The sources of sediments shown that Huye district had more polluter with turbidity 5080 NTU and TSS 1190 mg/L than from Nyamagabe district with turbidity 944 NTU and TSS 513 mg/L from soil erosion. The indirect impact, Huye district was more suspended to flood proportion with destruction of infrastructures near Mwogo river from sediments flocculated on base of river. In this study was illustrated that in two districts their required to invest in land protection activities as source of sediments but indicate the special needs at Huye district than Nyamagabe district in orientation of environment projects and other stakeholders in environment management through restoration of wetland and watershed by land cover and buffer zone promotion, runoff decrease rate via establishing the measures to minimize the impact of soil erosion in Mwogo river.

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Conflict of Interest

The authors declare no conflict of interest.

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Appendix

Table 3. RWFA observation and water quality standards.

	Parameter names	Parameter Short name	Mwogo water period I 2018	Mwogo water period II 2019	Natural potable water (FDEAS 12: 2018)	Discharged domestic wastewater (FDRS 110: 2017)	Unit
01	Hydrogen potential	PH	6.8	7.0	5.5 - 9.5	5 – 9	-
02	Total suspended solids	TSS	275	40	no detectable	50	mg/l
03	Turbidity	-	416	105	25	-	NTU

The data in table 3 were taken in period I (short rainy season) in November 2018, period II (short dry season) in February 2019 of Mwogo River water quality and water quality standards [10].

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