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Agricultural impact on environment and counter measures in Rwanda

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Rapid intensive agriculture often generates serious environmental concerns including soil erosion, water pollution and greenhouses gases. This paper assesses the impact of agriculture and its practices on environment in Rwanda from 1990 to 2012. Data provided by the World Bank were analyzed with Origin Pro 9 for statistical analysis. Also, a review on physical-chemical parameters and heavy metals of water resources home to or surrounded by cultivated mountains was adopted in this study. The results showed that agricultural records decreased from 1990 to 1994. However, after then, the short season cropland like cereals increased from 7.04 to 17.45%; roots and tubers increased from 13.17 to 21.69% in 1995 and 2012, respectively, whilst permanent cropland remained constant at 10.13%. As Rwandan soil is almost steep slope, this heavily exposes the soil to erosion, fertility loss and landslides as permanent crops to enhance fertility and erosion control are decreasing. Also, fertilizers increased from 2,149 to 27,748 tons, irrigation spaced from 4,000 to 10,000 ha which can be the reasons of rise of agricultural emissions. The reviewed studies estimated high concentration of the total nitrogen, total suspended solids, manganese, lead and iron exceeding the standards of the European Union and World Health Organization. From the above findings, it is suggested to regularly monitor water quality and promote its purification measures, to fertilize and irrigate timely and appropriately, expand areas under agroforestry and permanent crops, promote bench terraces practices for durable soil erosion control and water quality in Rwanda.

Key words: Agriculture, environment, Rwanda, soil erosion, water pollution.

INTRODUCTION

Emissions from agriculture, forestry and fishery worldwide, nearly doubled over the last 50 years and could increase at 30% in 2050 mainly being driven by population growth. Increasing size and usage of

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mechanized farm equipment and use of agrochemicals are negatively affecting the environment (Foley et al., 2011; Smith et al., 2008). Land use and land cover change through industrialization, urbanization and agricultural expansion are due to a strong dependence on natural resources (Ademiluyi et al., 2008; Brink and Eva, 2009; Foley et al., 2005). Agriculture is the backbone of Rwandan economy; it contributes 33% of the national GPD and 70% of the country' export revenues. The sector employs 80% of the population and can be subdivided into food crops (grown interchangeably in short period of time) namely cereals, root and tubers, leguminous and banana, cash crops also named permanent crops (coffee, tea and pyrethrum) and new crops introduced for cash/export reasons (fruits, vegetables, flowers and spices). Compared to the total cultivated land, more than 80% is occupied by food crops and approximately 6.3 and 1.6% by Coffee and Tea, respectively (Bizoza, 2014; Murenzi and Hughes, 2006; Ngabitsinze et al., 2011; REMA, 2014). Rwandan population is among the highest in Central and East Africa, as it grew from 2.996 million in 1961 to 11.4583 million in 2012 heading to 25.378 million in 2050 (Havugimana, 2009; NISR, 2012).

High demography with strong reliance on agriculture caused land scarcity, so that the per capita land decreased from 0.95 ha in 1960, 0.25 ha in 2010 leading to 0.10 ha by 2050. Forest cover decreased from 30% in 1930 to 8.9% in 2010 (Habiyaremye et al., 2011). In Rwanda, 16 to 40% of the land is steep slope easily exposed to soil erosion which causes approximately an annual loss of 1.4 million tons of fertile soil. This implies a high nutrients demand, (around 50% of all soils), due to the advanced level of erosion and acidity. Moreover, 63% of the irrigated area is on hillsides mostly depending on rainfall, while in dry season the productivity decreases, due to water insufficiency which finally leads to wetland degradation as the only productive area during dry periods (Giblin and Fuller, 2011; Kagabo et al., 2013; Kannan et al., 2011). All these facts accelerate the rate of fertilization and irrigation and natural resources degradation.

After the 1994 genocide against Tutsis, the country experienced a period of food insecurity due to high population growth rate (3.08 and 5.6% in 1996 and 2000, respectively), plus the war and genocide refugees coming back from neighboring countries. This led to consolidating policies for soil fertility enhancement toward higher agricultural production and caused cropland to increase from 14,850 Km^2 in 1995 to 18,567 Km^2 in 2012; the total arable land expanded from 7,000 to 11.817 Km^2 in 1995 and 2012, respectively. These changes were associated with the use of lime, organic manures, fertilizers and agroforestry, bench terraces and irrigation practices (Ansoms and Rostagno, 2012; Kathiresan, 2012; Rushemuka et al., 2014). Despite of the mechanisms consolidated, high population and its agricultural malpractices revealed natural resources degradation evidences. Previous studies have highlighted some of these efforts like increasing fertilizers application and crop land expansion on unprotected land, to be among the drivers to soil and water quality pollution through accelerating soil erosion and release of the phosphorus, nitrates and ammonia from agrochemicals applied, which in turn, cause water pollution and eutrophication (Hategekimana and Twarabamenya, 2007; Mupenzi et al., 2009; Wronski et al., 2015). These mechanisms merged may help in environmental protection, but on the other hand, under population growth and its rise in food demand, it can be predicted that, the magnitude is likely to increase negatively, if earlier interventions are not made. The objectives of this study are (1) to highlight the recent agricultural practices, (2) determine agricultural impact on land and water resources and (3) suggest future practices for agriculture and environmental sustainability in Rwanda.

MATERIALS AND METHODS

Description of the study area

Rwanda is located in East-central Africa and is bordered by Uganda to the north, Burundi to the south, Democratic Republic of Congo to the west and Tanzania to the east. Rwanda has two rainy seasons; the first starts from March to May and the last begins from October to November with an average rainfall of 110-200 mm per month. The first and short dry season starts from December to the end of February, while the longer one lasts from June to early September. Rwanda's average temperature ranges between 19 to 27°C (Giblin and Fuller, 2011) (Figures 1 and 2).

Data collection and analysis

This study used Statistical data from 1990 to 2012 by the World Bank Group (http://data.worldbank.org/country/rwanda) and encompasses data on the main crops grown (seasonal and permanent crops) and their appropriate land proportion compared to the total agricultural land, fertilizers and irrigation and agriculture and land use emissions. These data were analyzed by Origin Pro 9 for statistical analysis, to demonstrate changes on agriculture and its impact on environment with emphasis on land resources. To determine the impact on water resources, this study adopted the review methodology from previous studies conducted at Lake Muhazi, Akagera Transboundary River, Nyabugogo River, Rweru-Mugesera Wetland, Congo and Nile Basins (Rwandan Sub-catchments) and Kadahokwa Water Treatment Plant (Mupenzi et al., 2009; Nshimiyimana et al., 2010; REMA, 2014; RNRA, 2012; Sekomo et al., 2011; Usanzineza et al., 2011; Uwimana et al., 2010; Wali et al., 2011), where agriculture and human activities were attributed to the changes on physical-chemical parameters

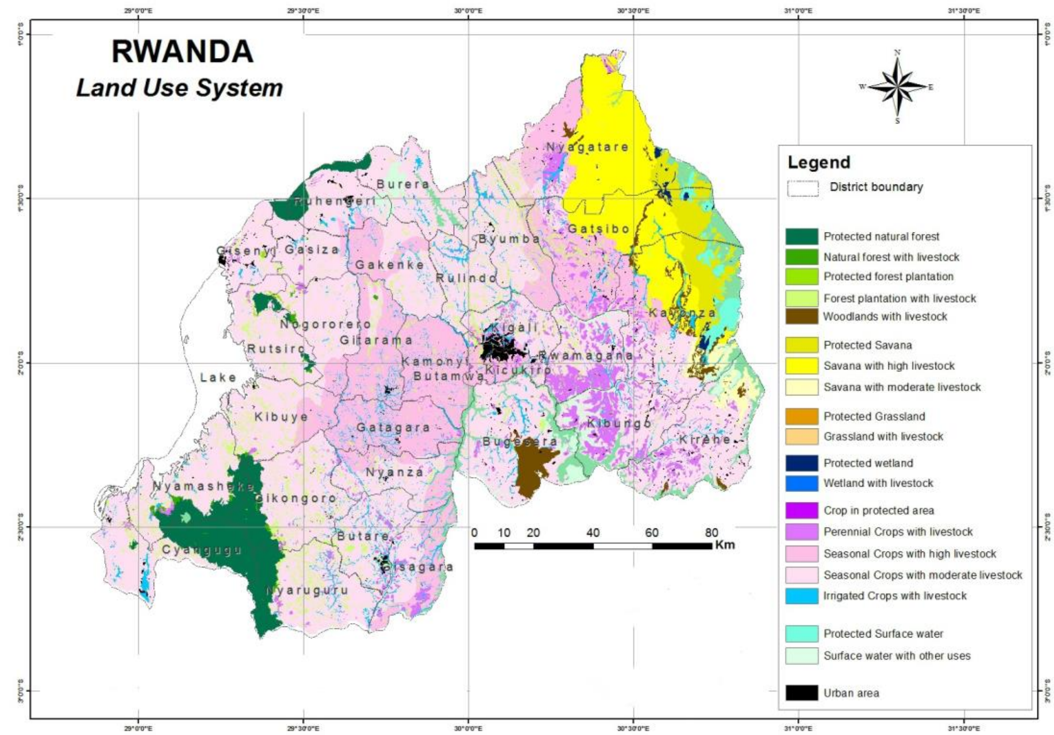

Figure 1. Land use system in Rwanda (Ernest et al., 2010).

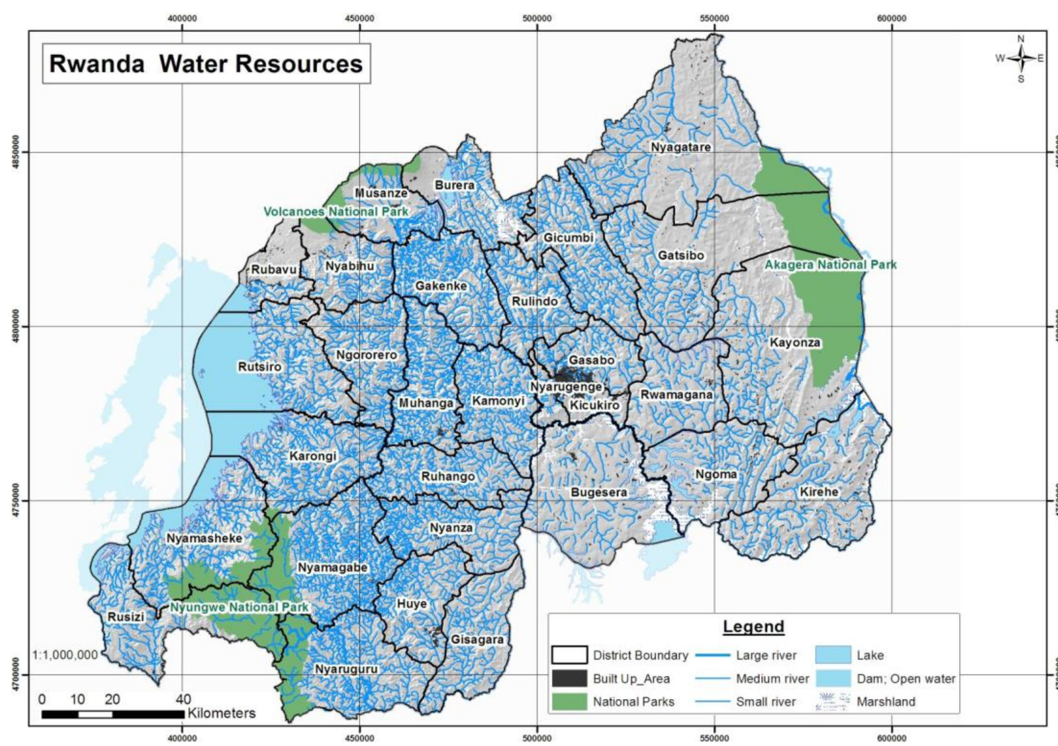

Figure 2. Rwanda's water resources network (REMA, 2014).

and heavy metals of these water resources considered (Tables 2 and 3). For these water quality studies reviewed, we only considered those conducted within the same time range as the present study, not later than 2012. Physical-chemical parameters like potential of hydrogen, total nitrogen, total phosphorus, total suspended solids, turbidity, ammonium-nitrogen, nitrate-nitrogen, dissolved oxygen and heavy metals like copper, zinc, lead, manganese, iron, chromium and cadmium were considered compared with the standards of the European Union (EU) (Wyness et al., 2003) and the World Health Organization (WHO) (WHO, 2004).

RESULTS

Agriculture, land uses and management

The study considered the main crops grown in Rwanda and their land proportion was compared to the total agricultural land as indicated in Figure 3.

Figure 3 shows that, after 1994, the percentage of permanent crops remains constant (10.13%) from 1997 to 2012. While the land area of cereals, roots and tubers, leguminous and other crops considerably increased. These cropland accounts indicate that land is not well used/managed due to lack of permanent crops.

Emissions from agriculture and other land uses in Rwanda

Figure 4 shows that the total land emission increased from 1990 to 2001, after then, the emission reduced until 2012. Contrarily, agricultural total emissions gradually keep on increasing with high marks in 2010 (3,059.01 Gg Co_2eq) (Figure 4).

This increase of agricultural emissions can be a result of expanding seasonal cropland than permanent crops (Figure 3), where, many fertilizers are applied and irrigation for high productivity in a short time, which in turn, can be the reasons for the rise of agricultural emissions. Detailed accounts of the size of Rwandan irrigated area and the use of fertilizers are illustrated in Table 1. It indicates that gradually both the use of fertilizers applied and irrigated area increased.

Agriculture and water quality in Rwanda

In this section, to show the evidences of agricultural impact on water resources, authors reviewed previous studies. In addition, the considered water resources as reported (methodology section), are home to agriculture or surrounded by cultivated mountains, with irrigation practices and fertilizers application which are not appropriately adapted to soil topography (Steep slope). As a consequence, this facilitates the transport of sediments and nutrients that pollute these water bodies (Tables 2 and 3).

DISCUSSSION

Agriculture in Rwanda encountered declined in production earlier and during 1994 Genocide against Tutsis. As a consequence of this instable situation, few people engaged in agriculture. However, five years after, population increased along with its food demand and policies like expanding the cropland area, increasing use of lime, organic manures and fertilizers, irrigation practices for the purpose of high productivity were applied (Booth and Golooba-Mutebi, 2014; Diao et al., 2010). These mechanisms can be the cause of expanding seasonal cropland (Figure 3) with high marked ups in the years of 2000 and 2010 along with increasing fertilizers applied and irrigated areas (Table 1). However, as stated by, Mulatu et al.(2014), Nabahungu, (2012) and Yeo et al. (2011), these land misuses lead to consequences like loss of ecological and socio-economic value of some species and lack of permanent crops to maintain those nutrients in the soil, which in turn, leads to soil infertility and facilitates erosion, which finally, reaches aquatic systems and result in associated pollution and eutrophication processes. It is possible to mention that, this is likely the expected results in Rwanda, if nothing is done to remove the gap between seasonal and permanent crops. The results of this study showed that agricultural emissions are continuously rising, while the total land use emission decreased (Figure 4), which can be a result of the efforts made by the Government of Rwanda on increasing the forest area from 12.89% to 18.62% in 1990 and 2012, respectively (REMA, 2011; WorldBank, 2015). Afforestation and reforestation helped in sequestering the gases emitted by soils, while agricultural land expansion gradually has been increasing its total emission.

However, as it has been reported, intensive agriculture, its increasing inputs (fertilizer and pesticides) and practices like enteric fermentation, irrigation and tillage and mechanization, crop residues burning, lead to emissions of N_2O, CH_4 and CO_2 which in turn, contribute to soil, air and water quality pollution with more effects on poor countries whose adaption measures are not sufficient (Barber and Quinn, 2012; Braune and Xu, 2010; O'Geen et al., 2010). By considering how faster agriculture is expanding in Rwanda, it is possible, that under the expansion of seasonal cropland (Figure 3), the increased forest area

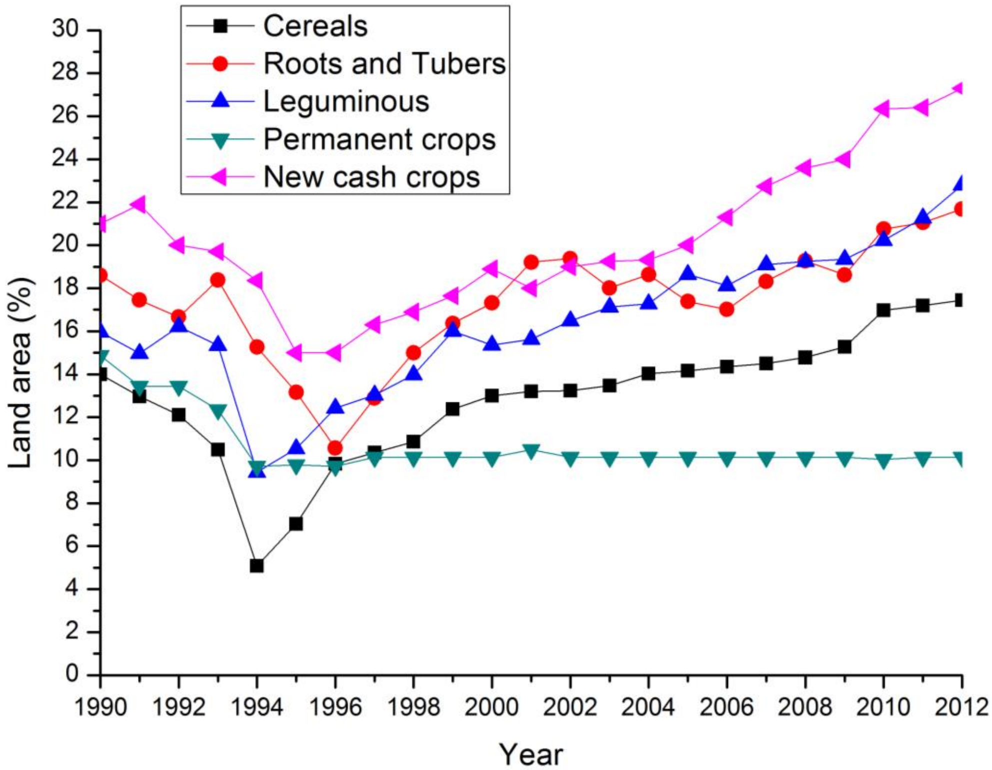

Figure 3. Land Proportion of different crops in Rwanda from 1990 to 2012.

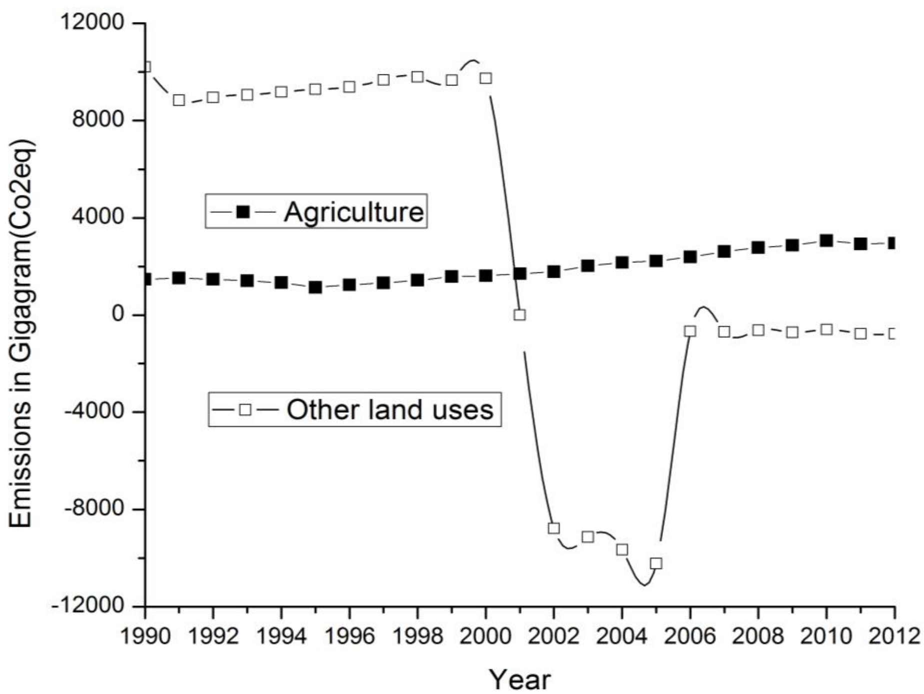

Figure 4. Total agriculture and other land use emissions in Rwanda (1990 to 2012).

Table 1. Irrigated area and use of agricultural fertilizers in Rwanda.

Year	1990	1992	1997	2002	2007	2012
Fertilizers (Tons)	2.149	6.143	3.858.8	5.835	10.989.8	27.748
Irrigated area (ha)	N/A	4.000	7.000	9.000	10.000	10.000

N/A: Not Available and ha: hectare Source: World Bank (2015).

Table 2. Estimated physical-chemical parameters of the reviewed studies.

Places	PH	TN	TP	DO	Turbidity	TSS	NO_3-N	NH_4^-N	Sources
Lake Muhazi	7.8	1.2	0.18	n/s	n/s	n/s	0.489	n/s	Usanzineza et al. (2011)
Rweru-Mugesera wetland	5	3.8	1.73	1.32	n/s	67.91	n/s	n/s	REMA (2014)
Nyabugogo River	5.9	0.14	0.12	4.3	2750	n/s	43	0.54	Sekomo et al. (2011)
Congo Basin (Rwanda)	7.6	n/s	0.38	4.8	4805	920.90	n/s	n/s	RNRA (2012)
Nile Basin (Rwanda)	7.7	0.93	0.20	4.21	780	162.86	n/s	n/s	RNRA (2012)
EU and WHO Standards	6- 8	<3 mg/l	<5 mg/l	5 mg/l	5NTU	<30 mg/l	50 mg/l	0.50 mg/l	WHO (2004) and Wyness et al. (2003)

n/s: not specified, TN: Total Nitrogen, TP: Total Phosphorus, DO: Dissolved Oxygen, TSS: Total Suspended Solids, NO_3-N: Nitrate-Nitrogen, NH_4-N: Ammonium Nitrogen, mg/l: milligram per liter, NTU: Nephelometric Turbidity Unity, EU: European Union and WHO: World Health Organization.

may be undermined for crop land reasons, being associated with increasing fertilizers application and expansion of irrigated areas (Table 1), which in turn, lead to increasing agricultural emissions. This, is in congruent with the reports of Kannan et al. (2011) and Rushemuka et al. (2014), that Rwanda is ahilly and rainy country, where fertilizers are applied and irrigation is practiced on unprotected soil, without great consideration of how much the soil is easily eroded due to agricultural malpractices and its natural topography (steep slope).

In addition, Fidèle et al. (2015) assigned subsistence agricultural malpractices, lack of timely updates and approaches to farmers to be the leading causes of soil erosion and water pollution in Rwanda, as evidenced by the reviewed water resources, where some physical-chemical parameters and heavy metals (Tables 2 and 3) were estimated to be higher than the standards of the European Union (EU) and the World Health Organization (WHO). It is good to reach farmers and invest more on soil erosion control as indicated by Fialho et al. (2013), Mupenzi et al. (2009), that terraces and agroforestry can be a good alternative , which also helps in water quality enhancement, since the rosion which transports sediments and nutrients into water is minimized. For agriculture and environmental sutainability in Rwanda, a developing country high demography with strong reliance on subsistence agriculture, expanding seasonal crops than permanent crops and more inputs, it can be predicted that, much is likely to happen in terms of environmental quality degradation, particularly land and water resources, if intervention policies are not well practiced and strengthened.

Conclusion

This study considered agricultural practices to assess its impact on environment. The results showed that seasonal cropland expanded compared to permanent crops. Fertilizers and irrigation increased with agricultural emissions with pollution impact on both soil and water as the cultivated soil is almost steep slope easily facilitating erosion. For more environmental friendly practices in case like Rwanda, with a rapid growing population only relying on subsistence agriculture, it is suggested to:

(i) Reduce the incidence of fertilizers with more emphasis on organic farming systems.
(ii) Increase the area of permanent crops, agroforestry and bench terraces for soil erosion control and water quality management.
(iii) Transform the sector from household size into group cooperatives to improve its professionalism.
(iv) Promote institutional and technical assistance to improve local farmer's awareness on timely and appropriate fertilizers to apply and irrigation and their impact on natural resources.

Initiation and/or reinforcement of the polluter pay principle and Increase the awareness and share the

Table 3. Estimated heavy metals of the reviewed studies.

Places	Zn	Cr	Cu	Mn	Fe	Cd	Pb	Sources
Lake Muhazi	0.04	0.00	0	0.34	0.75	0.02	0	Usanzineza et al. (2011), Nshimiyimana et al.(2010) , Sekomo et al. (2011), RNRA (2012)
Akagera Transboundary River	0.55	0.01	0.41	14.64	0.56	0.96	0.04	
Nyabugogo River	0.10	n/s	0.02	n/s	n/s	0	n/s	
Congo Basin (Rwanda)	0.05	n/s	0.02	0.08	1.4	n/s	n/s	
Nile Basin (Rwanda)	0.21	n/s	0.02	0.23	1.32	n/s	n/s	RNRA (2012)
Kadahokwa	0.04	0.03	0.04	n/s	n/s	0.01	0.04	Uwimana et al. (2010)
EU and WHO Standards (mg/L)	5	0.05	2	0.05	0.3	0.03	0.01	WHO (2004) and Wyness et al. (2003)

n/s: not specified, Zn: Zinc, Cr: Chromium, Cu: Copper, Mg: Manganese, Fe: Iron, Cd: Cadmium, Pb: Lead, EU: European Union, WHO: World Health Organization and mg/l: milligram per liter. For both Tables 2 and 3, the highlighted Bold values indicate those exceeding the standards set out by the European Union (EU) and the World Health Organization (WHO).

responsibilities on environmental protection between policy makers, those in charge of implementation and the local community.

Conflict of Interests

The authors have not declared any conflict of interests.

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