Potential Impact Assessment of Agricultural Practices on Water Quality in Nyanza District; A Case Study of Bishya Wetland

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***Abstract*— *A challenge of linking agricultural sector with water quality in order to combat water pollution remains worrying for the Government of Rwanda. The general objective of the study was to assess the potential impacts of agricultural practices on water quality in NYANZA District. Specifically, the study assessed agricultural practices in Bishya wetland, analyzed the level of water pollution in Bishya wetland, and demonstrated the correlation between agricultural practices and water quality from Bishya wetland. Data were obtained through questionnaires, observation, and laboratory analysis of water samples taken twice per month in six sampling points of bishya dam situated in bishya wetland starting from 4th March 2019 up to 20th August 2019. The Linear Regression Model using SPSS statistics with 95% confidence interval was used to demonstrate the correlation between agricultural inputs and water quality data for all selected physico-chemical parameters. Findings revealed that agricultural practices in Bishya wetland and surrounding areas are characterized by the presence of different crops, ineffective anti-erosions, absence of wetland margins, ineffective drainage of wetland, use of organic manures and chemical fertilizers, as well as the presence of different types of rocks and soils. Findings revealed also that all parameters have not manifested pollution, but some of them did according to Rwanda Standard Board guidelines. In sampling point1, the parameters that presented pollution were nitrites (r=0.047), phosphates(r=0.384), iron (r=0.11), and manganese(r=0.018); in sampling point2, were nitrites(r =0.010), iron (r=0.059), and chemical oxygen demand(r=0.012); in sampling point 3, were pH (r=0.048), nitrites(r =0.086), and phosphates (r=0.329); in sampling point 4, were nitrites (r =0.123), iron(r=0.182), and manganese (r=0.051); in sampling point 5,were turbidity (r=0.080), nitrites (r=0.095), phosphates(r=0.188),iron(r=0.093), manganese(r=0.051), and chemical oxygen demand(r=0.017), and in sampling point 6, the parameters that presented pollution were nitrites(r=0.046), phosphates(r=0.277), iron(r=0.106), and manganese(r=0.190). Finally, findings revealed that agricultural practices in Bishya wetland and surrounding areas, have contributed to the pollution of water quality of Bishya dam through substances of organic manures, chemical fertilizers and pesticides, crop residues, and soil sediments that are transported into the dam by erosion. The study concluded that an effort to create anti-erosions in all areas surrounding wetland, respectful of buffer zones, improving vegetation covers, creating water management bodies at cells level, increasing awareness of population about ecosystem functions, and capturing rain water from houses may effectively contribute to water quality in Bishya wetland.*

Keywords*— *Agricultural practices, water quality, water pollution, and Bishya wetland.

I. INTRODUCTION

Water is a key natural resource, which is very important to all ecosystems on the earth surface (UNESCO, 2006). It is a fundamental element for all forms of life for various purposes such as agriculture, drinking, cleaning, and as shelter for aquatic organisms (Ninhoskinson, 2011). Water covers 70% of the Earth's surface, yet 40% of the world's peoples experience water shortage (Mmbando J. et al, 2007). Access to clean and safe water is a basic necessity of human life, and one of the most important global issues (Larsen, 1997). According to WHO, quoted by Mmbando J. et al (2007), 1.4 billion people, equivalent to 20% of the world's population, do not have access to clean and safe water. It is mainly the poorer Less Economically Developed Countries (LEDCs) who have least access. This lack of access is a major barrier to a country's development (Mmbando J. et al, 2007). No single measure would do more to reduce disease and saves lives in the developing world than bringing safe water to all (Koffi Annan, 2000). One of the main reasons for the shortage of water is that 97.5% of the water that covers the Earth is saltwater, whilst just 2.5 % is fresh water.

In Africa, up to 90% of freshwater is used in agriculture. The WHO, quoted by Mmbando J. et al (2007), it is estimated that 17% more freshwater will be needed simply to grow enough food to cope with the estimated increase in population. Rapid population growth has put pressure on the world's resources and affected quality of life. Half of all the populations in LEDCs still do not have safe water to drink. Contaminated water is responsible for the cause and spread of 80% of the world's disease including cholera, typhoid and dysentery (WHO, 2006). Waterborne diseases kill 25000 people daily, and about 14 million children under five-year old die each year from illness and hunger (Mmbando J. et al, 2007).

Although human beings benefit a lot from water, they are among the main causes of water pollution through poor management of agricultural practices (US-EPA, 1994). These include excessive use of fertilizers for increasing production, traditional irrigation practices, use of pesticides and herbicides and poorly managed animal farming operations (EPA, 2009). The rapid population growth in LEDCs has resulted in environmental degradation and remarkable reduction in cultivable land. Agricultural smallholders dominate the scarce land available and the smaller the land, the more likely the landholder to live in poverty (IDA, 2008). Water management in degraded environment and in a very limited cultivable land is considered as a big challenge for the much-needed expansion of basic services including water services, which cannot be expanded at the desired quality and quantity; thus the need for a new approach to improving water provision in such degraded environment and limited cultivable land (Schreinemachers, 2012).

In Rwanda, the Government has adopted some policies like enhancing irrigation practices, use of fertilizers, expanding the cropland area, increasing use of lime and organic manures, all aim at increasing agricultural productivity and eliminating poverty among citizens (Nahayo et al, 2016). Besides, the Government of Rwanda adopted the National Water Services Strategy through which the Government is committed to fast tracking affordable and sustainable access to safe water in the settlements of both rural and urban areas. This is achievable through defining national standards for low-cost technologies and increasing number of public or communal outlets under formal water service provision (WASAC, 2018). However, these practices adopted for increasing agricultural production have resulted in water quality deterioration through hurrying soil erosion and release of phosphorus, nitrogen and other chemical substances from agrochemicals applied, which in round, cause water pollution and high levels of eutrophication in wetlands and some lakes (REMA, 2009).

Agricultural inputs have been identified as one of the leading sources of water pollution in Rwanda, especially in wetlands (REMA, 2009).The worsening of fresh water quality can be directly observed through water utilities in a country. For instance, the amount spent on acquiring chemicals to treat water constitutes a huge part of any water utility's expenditure. The Rwandan Water Utility (WASAC) spends millions of Rwandan Francs on water treatment chemicals where in 2017/2018 an amount of 96 million Rwandan Francs have been spent for the purification of water in NYANZA town alone (WASAC, 2018). The amount spent on chemicals rises with the deterioration of raw water quality and this in turn makes water expensive, as the water utilities are forced to adjust water prices to recover costs. Some researches related to agricultural policies, crop production have been conducted in Rwanda; however, a challenge of linking these sectors with water quality in order to combat water pollution remains.

II. MATERIALS AND METHODS

2.1 Description of the study area

Bishya wetland is located between Busasamana, Rwabicuma and Mukingo Sectors of Nyanza district in the Southern Province of Rwanda. It is situated on the plateau agro-ecological zone of Rwanda at approximately 19500 m, covers an area of 17km^2. The annual range of rainfall in Bishya Wetland is 1200 mm–1400 mm (Nyanza District report, 2018).

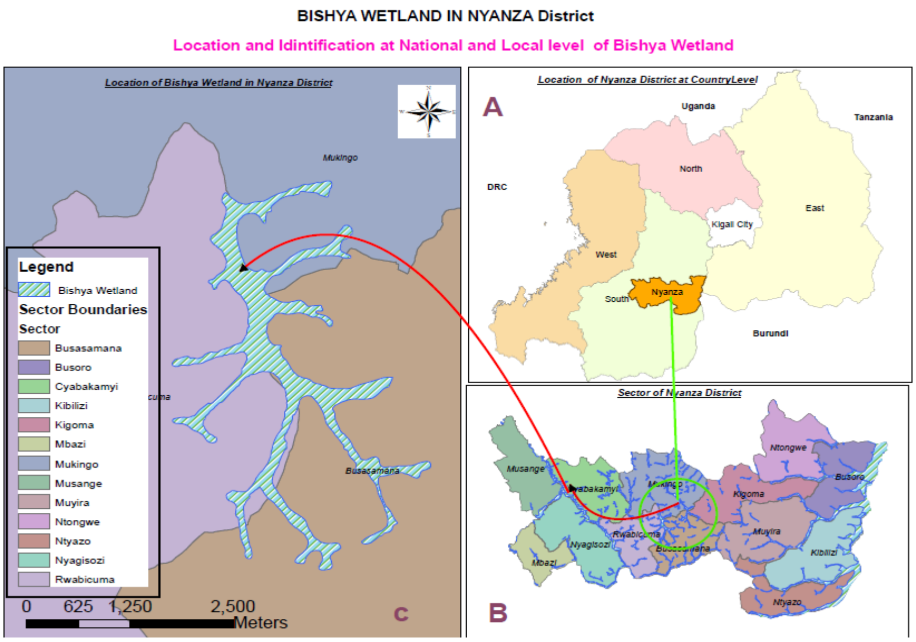

FIGURE 1: Bishya wetland

Bishya wetland has been exploited in an unorganized way for a long time where people cultivated different crops such as sweet potatoes, maize, beans, sorghum, etc. Since 2015, this wetland was divided into two parts: one part (downstream) was constructed in valley dam and the second part (upstream) is used for agricultural activities and sericulture (Nyanza District report, 2018).

2.2 Research design

A research design is considered as a master plan specifying the accurate methods and procedures for collecting and analyzing the required information. Hence, this study used qualitative and quantitative methods. In regard to qualitative method, the researcher distributed questionnaires to farmer cooperatives operating in Bishya wetland and surrounding areas. Furthermore, the researcher's own observation was needed for supplementary information. In terms of quantitative method, the researcher has selected six sampling points in bishya dam basing on different entrances of different streams passing through the areas characterized by different agricultural plantations (maize for sampling point1 and 2, mulberry for sampling point3, vegetables for sampling point4, cassava and sweet potatoes for sampling point5, and the dam intake in water supply for the sampling point6). Furthermore, a Linear Regression Model using SPSS statistics with 95% confidence interval was used to analyze the correlation between agricultural inputs and water quality from Bishya dam.

2.3 Study population

The population, under this study, was composed of all farmer cooperatives performing agricultural activities in Bishya wetland and surrounding areas, which the total number is five cooperatives, namely NGIRANKUGIRE and SHINGISUKA cooperatives, both maize farming, TURENGERABANA cooperative, vegetable growers, TURWANYINZARA cooperative, sweet potatoes and cassava farming, and HEworks Rwanda Silk Ltd, mulberry cultivation.

2.4 Source of data

The study involved the use of primary data and secondary data. Primary data were collected through questionnaires, observation, and laboratory tests of raw water from Bishya dam. Secondary data from books and official reports

2.4.1 Questionnaire

The closed and open-ended questions were given to five representatives of five different farmer cooperatives performing their agricultural activities in Bishya wetland and surrounding areas. In general, the survey was designed to know the characteristics of agricultural practices in Bishya wetland, and basing on these characteristics to assess their potential impact on the water quality from Bishya dam.

2.4.2 Observation

The author did his own observation on field for different times, in dry and rainy seasons of 2019, in order to ensure himself the agricultural features in Bishya wetland and surrounding areas.

2.4.3 Laboratory tests of water from Bishya dam

2.4.3.1 Water sampling

The water samples were collected twice per month from Bishya dam for a period of six months starting from 4th March 2019 up to 20th August 2019. Subsequently, twelve sampling campaigns were conducted during that period for the six sampling points in the dam. Samples were collected and stored in 500ml plastic bottles. The plastic bottles were washed and rinsed with distilled water before use. Samples were put in a cooler box for preservation during transportation to the laboratory for analysis. Then, samples were kept in a fridge at 4^{o}c to avoid any external contamination while preparing the laboratory equipment and reagents to be used in testing of different selected physico-chemical parameters.

2.4.3.2 Laboratory analysis

Water samples from the Bishya Dam were collected and analyzed in Laboratory of WASAC at MPANGA water treatment plant. Samples were analyzed using standards procedures for testing water and wastewater (APHA, 2005). The physico-chemical parameters analyzed in this research were pH, turbidity, nitrites, nitrates, ammonia nitrogen, phosphates, iron, manganese, and chemical oxygen demand.

2.4.4 Data analysis procedure

The collected data was processed, analyzed and managed using editing, tabulation, and graphics in order to provide clear and understandable data. Furthermore, Linear Regression model with 95% confidence interval was used to establish potential correlation between agricultural inputs and water quality parameters. Hence the results from laboratory and had positive correlation with agricultural inputs were compared to the Rwanda Standards Board (RSB) guidelines for natural fresh water in order to analyze the level of water pollution from agricultural practices in Bishya wetland.

III. RESULTS AND DISCUSSIONS

3.1 Assessment of agricultural practices in Bishya wetland and surrounding areas

3.1.1 The opinions of respondents

In terms of agricultural production, all respondents (100%) have insisted on mulberry, maize, vegetables, sweet potatoes, banana plantation, and cassava as the main agricultural production performed in Bishya wetland and surrounding areas. This situation shows that agricultural production, in Bishya wetland, are varied crops necessitating various fertilizers and pesticides to grow.

Regarding the cooperative farm size and grown crop, NGIRANKUGIRE and SHINGISUKA grow maize on respectively 76ha (25.7%) and 59ha (20.0%), TURENGERABANA grows vegetables on 52ha (17.6%), TURWANYINZARA grows sweet potatoes and cassava on 51ha (17.2%), and HEworks Rwanda Silk Ltd that grows mulberry at 57ha (19.3% of the total exploited land). This situation shows that Bishya dam's surrounding land is sufficiently exploited, and accommodates various crops that necessarily require various fertilizers and pesticides to grow up and to produce more.

Regarding the frequency of using fertilizers and pesticides in cooperative farms, the majority of respondents (80%) confirmed that they regularly use fertilizers and pesticides in their farms, while only 20% highlighted that the use of fertilizers and pesticides in their farms is done sometimes. None of cooperatives denied the use agricultural inputs. Those who irregularly use agricultural inputs are farmer cooperative that grows sweet potatoes and cassava. This situation confirms that agricultural practices in Bishya wetland and surrounding areas are characterized by the use of different fertilizers and pesticides.

Regarding the types of fertilizers and pesticides usually used in farm crops of Bishya wetland and surrounding areas, the majority of respondents (80%) regularly use organic manure as fertilizers; 60% of respondents frequently use NPK17*17*17, DAP, Urea, and insecticide composed of Cypermethrin 40% and Profenofos 40%), and fungicide; 60%of respondents repeatedly use chlorpyrifos-ethyl, 40% of respondents often use thiram and benomyl as pesticides, while only 20% of respondents regularly use NPK20*10*10 and lime as agricultural input. This situation confirms that agricultural practices in Bishya wetland and surrounding areas are characterized by the use of different chemical fertilizers, organic manures and pesticides as agricultural inputs.

In terms of quantity of fertilizers and pesticides used in farming crops in every season, NGIRANKUGIRE cooperative, which grows maize, uses NPK (19,000kgs), organic manure (380,000kgs), and Chlorpyrifos-ethyl (76kgs); SHINGISUKA cooperative, which also grows maize uses NPK (14,750kgs), organic manures (295,000kgs), and Chlorpyrifos-ethyl (59kgs); TURENGERABANA cooperative, which grows vegetables, uses organic manures (260,000kgs), Urea (4160 kgs), DAP (5,200 kgs), Fungicide (52 kgs), and insecticide (52kgs); TURWANYINZARA cooperative, which grows cassava and sweet potatoes, uses organic manures (357,000 kgs); and HEworks Rwanda Silk Ltd, which grows mulberry, uses NPK20*10*10 (24,510kgs)

For the question to know if farmer cooperatives have received any agriculture input aid within season B of 2019, the majority of farmer cooperatives (80%) have received agricultural inputs; while only 20% did not received. This was confirmed by Agronomist of Nyanza District during the interview conducted to him, where he said that farmer cooperatives are given priority in provision of agricultural input aids known as NKUNGANIRE program, basing on priority crops (A farmer pays 25% and Government pays 75% of the total prices of agricultural inputs). This situation shows that, basically, farmers have advantages from joining farmer cooperatives. The situation highlights also that farmer cooperatives apply all necessary quantity of chemical fertilizers and pesticides according to the requirements of MINAGRI since they get these agricultural inputs under the form of aids from the Government of Rwanda.

3.1.2 The author's own observation

During our own observation on field for different times, in dry and rainy seasons of 2019, we realized that agricultural features in Bishya wetland and surrounding areas, are mainly composed of ineffective anti-erosions, existence of different types of rocks and soils, the misuse of organic manures and chemical fertilizers, absence of vegetation covers, absence of wetland margins, and ineffective drainage of wetland. This weak management of Bishya wetland remains a major challenge, despite the efforts made by the Government of Rwanda at improving wetlands management over the years.The following figures highlight ineffective management of Bishya wetland

FIGURE 2: Crop farming activities

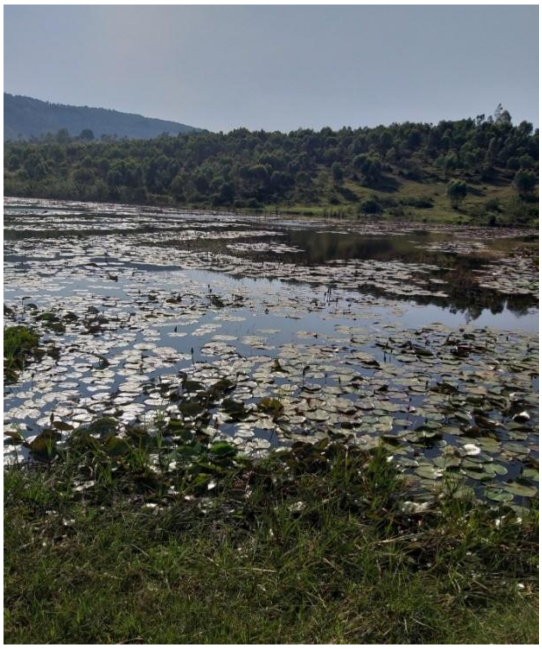

FIGURE 3: The concentration level of water hyacinth

3.2 Laboratory tests of water samples

3.2.1 The sampling points

Six water-sampling points were selected basing on different entrances of different streams passing through the areas characterized by different agricultural plantations namely mulberry, maize, vegetables, cassava and sweet potatoes. Therefore, two points were selected to represent the upstream of the Bishya dam where two streams from the farms owned by NGIRANKUGIRE and SHINGISUKA cooperatives that grow maize fall in the dam (P1, P2). Other two points, P3 and P4, were chosen basing on entrances of different streams passing through mulberry and vegetable plantations owned by HEworks Rwanda Silk Ltd and TURENGERABANA cooperative respectively. The sampling point P5 was selected basing on entrance of stream passing through the plantation of sweet potatoes and cassava owned by TURWANYINZARA cooperative. Finally, the sampling point P6 is the dam intake for water supply systems in NYANZA District. Pictorial location of the sampling points within the Bishya dam (Figure 4).

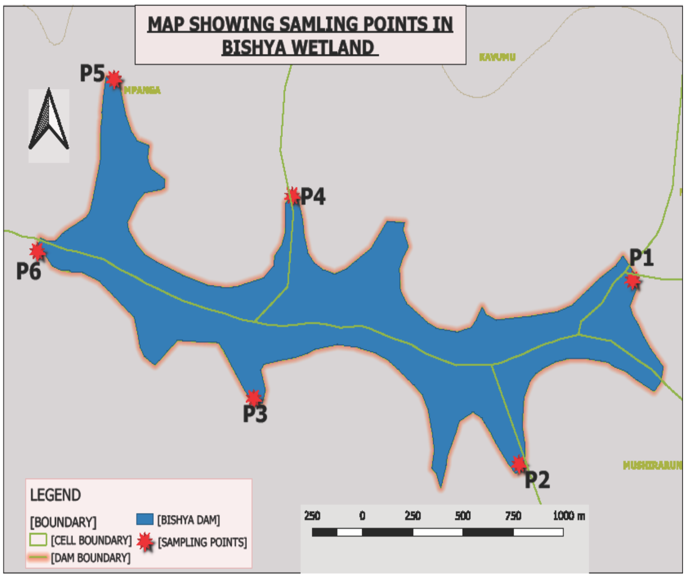

FIGURE 4: Sampling points within the Bishya dam

3.2.2 Presentation of the results of physico-chemical parameters from laboratory tests.

This section presents findings from laboratory analysis and then presents the graphical analysis of data. In order to interpret and be able to draw suitable conclusions on our research the linear regression model has been conducted. From the 4th March2019 up to the 20th August 2019, water samples from Bishya Dam have been taken and brought to laboratory for the analysis. Below we present the average values and standard deviation of different physico-chemical parameters for each sampling point.

TABLE 1
AVERAGE VALUES OF DIFFERENT PHYSICO-CHEMICAL PARAMETERS FOR EACH SAMPLING POINT

Sampling points	P1	P2	P3	P4	P5	P6	RSB standards
	N=12	N=12	N=12	N=12	N=12	N=12	
PH	6.06±0.22	6.04±0.35	5.25±0.24	5.65±0.54	5. 84±0.45	5.73±0.29	**5.5-9.5**
Turbidity(NTU)	74.85±14.28	80.78±29.8	114±50.56	58.33±22.46	49.17±13.05	51. 9±27.8	**25**
Nitrites (mg\L)	1.15±0.11	1.09±0.11	1.12±0.08	1.18±0.07	1.21±0.05	1.15±0.05	**0.9**
Nitrates (mg\L)	3.79±0.50	3.88±0.52	3.74±0.47	3.50±0.59	3.18±0.17	3.78±0.46	**45**
Ammonia Nitrogen (mg\L)	0.36±0.14	0.38±0.18	0.40±0.10	0.27±0.06	0.24±0.08	0.28±0.08	**0.5**
Phosphate (mg\L)	2.49±0.16	2.35±0.12	2.35±0.13	2.38±0.18	2.33±0.12	2.50±0.13	**2.2**
Iron (mg\L)	2.64±0.34	5.60±0.52	5.23±0.50	2. 80±0.26	2.41±0.47	2.37±0.49	**0.3**
Manganese (mg\L)	0.14±0.04	0.64±0.25	0.78±0.34	0.26±0.03	0.26±0.03	0.21±0.03	**0.1**
COD(mg\L)	46.50±10.24	58.41±10.4	52.3±10.4	53.4±12.8	51.00±8.22	49.00±8.53	**50**

Water quality parameters described in the Table 1 have been selected on basis of some aquatic plants that can be an indicator of a water rich in some chemical substances present in the dam such as water hyacinths and also basing on fertilizers and pesticides that are used in agricultural activities in this area. Moreover, the table indicates the average values and standard deviation of the physico-chemical parameters for each sampling point in Bishya dam. It also indicates the RSB standards to compare with these average values and then to demonstrate the level of pollution.

3.2.2.1 Results from PH laboratory test

The pH is an important parameter in water as it can indicate whether organisms or substances can exist in water for any value of the pH. Figure 5 illustrates the average values of pH in six sampling points.

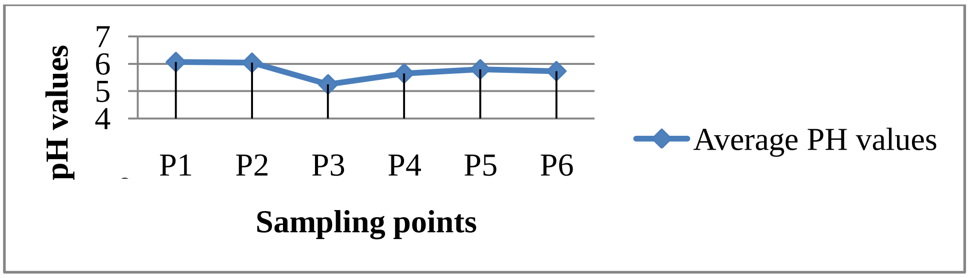

FIGURE 5: Average pH values according to sampling points in Bishya dam

This graph indicates that the pH in sampling point 3 was more acidic than other sampling points with average pH value of 5.25 overtaking the minimum limit of 5.5 recognized by RSB. The lower pH means that the water can provoke redness and irritation of eyes for the people during the usage and also can cause corrosion of metal pipes of the water supplying systems (Ombaka,2013).The acidic behavior of water in bishya dam especially in P3 could be due to dissolved carbon dioxide and organic acids derived from the decayed matter which then eventually fall into the water body. The sampling points P1, P2, P4, P5, and P6 were less acidic with means pH values of 6.06, 6.04, 5.65, 5.84, and 5.73, respectively and these values fall in acceptable limits of RSB.

3.2.2.2 Results from Turbidity laboratory test

The average values of water parameters from laboratory results as presented in table1showed that turbidity is high in all sampling points ranging from 49.17NTU to 114 NTU. These average turbidity values overtake accepted limits of RSB that is fixed at 25NTU.

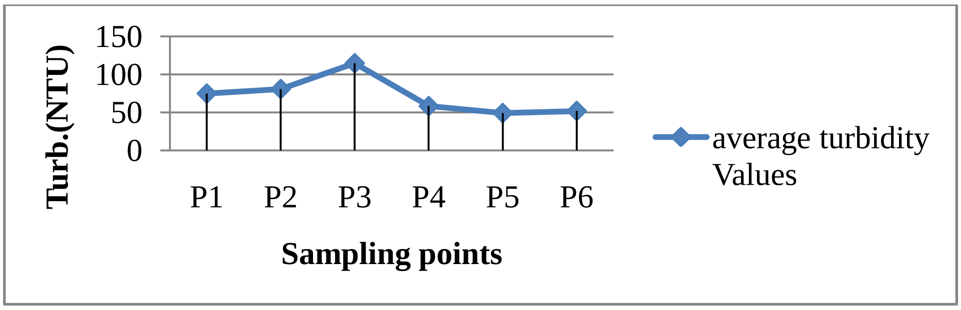

FIGURE 6. Average turbidity values according to sampling points in Bishya dam

From the above graph, it is observable that in sampling point P3 located in the area of mulberry plantation the turbidity level was very high comparing to other sampling points though all of them present the level overtaking the accepted limits of RSB. This situation means that in all sampling points, suspended particles, the presence of organic and colloidal materials from agricultural runoff and soil sediments contribute towards high turbidity values, especially in rainy season according to Thirupathaiah, 2012. Turbidity can give shelter for microorganisms and pathogens in water and also Turbidity of water has an impact on other parameters such as color and even chemical parameters which affect water quality (Ombaka, 2013)

3.2.2.3 Results from Nitrites laboratory test

Nitrites are among substances that have been analyzed in this research since we noticed that they have an impact on the pollution of water in Bishya dam. The laboratory tests for Nitrites have shown that average concentration of nitrites varies from 1.09 mg/l to 1.21mg/l. These all mean values are above the RSB guideline, which is 0.9mg/l.

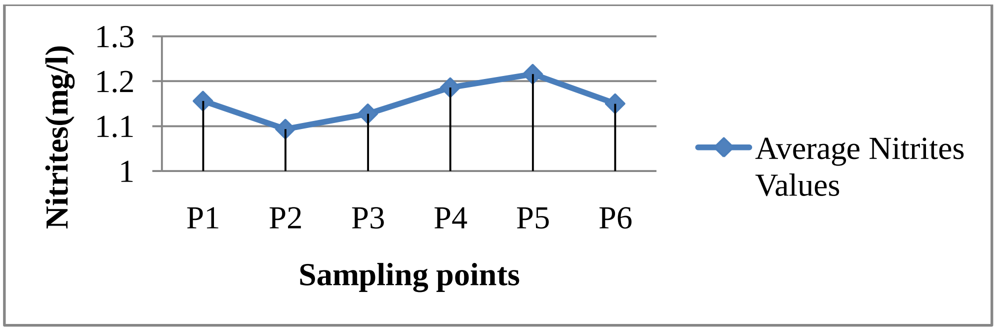

FIGURE 7: Average of nitrites concentration according to sampling points in Bishya dam

The above graph shows that the average nitrites levels was high in sampling point P5 comparatively to other points, though all sampling points present the mean values overtaking the accepted limit of RSB. This situation showed that activities performed in P5 produce substances containing high quantity of nitrites comparing to other points. Considering detailed results from each sampling points in different seasons, it was observable that nitrite concentration increased in the dry season than in rainy season in all sampling points. This situation proves the theory that when the volume reduces the concentration increases. In dry season, the rain is reduced and there is a too much evaporation, which finally results in the reduction of volume of water in the dam and increase of concentration of chemical substances in general.

3.2.2.4 Results from Nitrates laboratory test

Nitrates have been selected among parameters to be analyzed as they can contribute in water pollution of the dam since they are much more abundant in intensive agricultural runoff. From the laboratory tests nitrates have shown that the average concentration of nitrates varies from 3.18 mg/l to 3.88mg/l in all sampling points. However all mean concentration levels were within the RSB standards of 45mg/l.

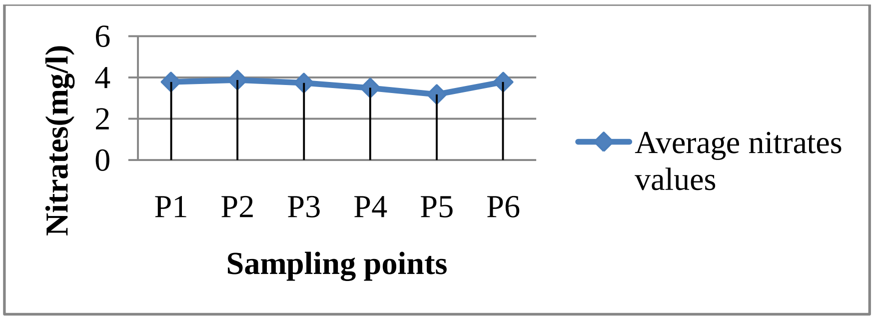

FIGURE 8: Average of nitrate concentration according to sampling points in Bishya dam

From the above graph it is noticed that concentration of nitrates didn't vary too much, since the difference in average values is not high. The sampling point P5 presents a less concentration level of 3.18 mg/l; this point is traceable on the side of sweet potatoes and cassava plantations.

3.2.2.5 Results from Ammonia nitrogen laboratory test

The ammonia nitrogen in water body comes from different sources but in our research, we focused the ammonia nitrogen which comes from fertilizers that are used in the area of our research. In this area, it is known that runoff that enters Bishya dam contains ammonia nitrogen that can have a negative impact on water quality.

Laboratory results have shown an average concentration level of ammonia nitrogen swinging between 0.24mg/l and 0.49mg/l for all sampling points. These all average values were within the limits accepted by RSB of 0.5 mg/l.

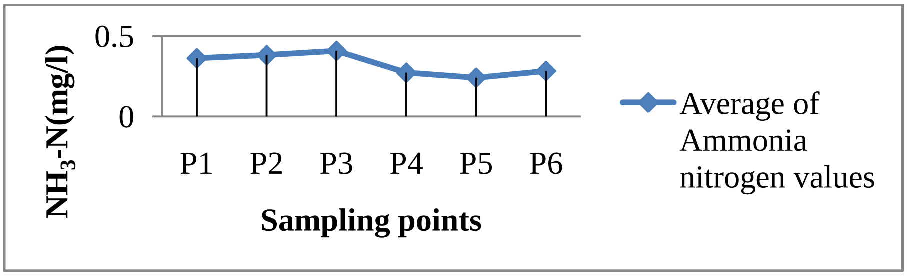

FIGURE 9: Average of ammonia nitrogen values according to sampling points in Bishya dam

The graph indicates that the concentration of ammonia nitrogen was on high in sampling point 3, which located on the side of mulberry plantation. Even if laboratory tests for ammonia nitrogen (NH_3-N) shown that the mean values did not overtake RSB guideline which is 0.5mg/l, the trend situation was not negligible in all sampling points. Moreover, the results indicated that Bishya dam had some quantities of organic matters in it, and provoke the water to have a bad smell (indication of water quality deterioration).

3.2.2.6 Results from Phosphates laboratory test

As other parameters analyzed in this research, phosphates from agricultural runoff contribute to the deterioration of water quality in the dam. Laboratory tests for phosphates have shown phosphates concentration level varying between 2.33 mg/l and 3.50 mg/l in all sampling points. These average values present pollution cases in Bishya dam since they are all above accepted limit of RSB which is 2.2 mg/l.

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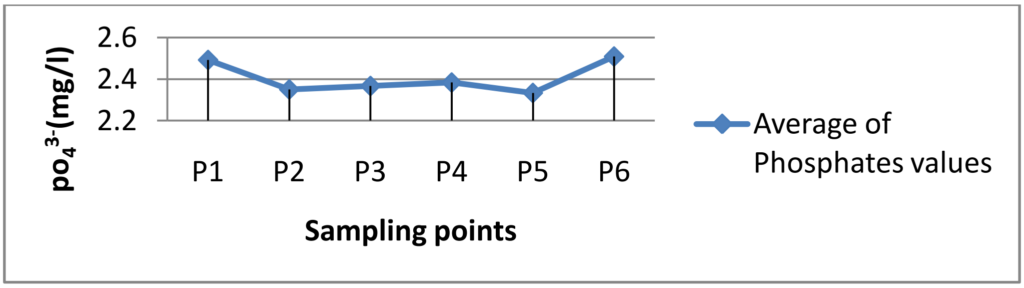

FIGURE 10: Average of phosphate concentration according to sampling points in Bishya dam

The analysis from the graph shows that there is high concentration levels in P1 and P6 corresponding to 2.49mg/l and 2.50mg/l respectively, comparatively to other points. This means that in sampling point1 and 6, the dam accommodates a large quantity of substances containing phosphates ions than others.

3.2.2.7 Results from Iron laboratory test

Laboratory tests for iron have shown that the concentration level of iron in Bishya dam varies between 2.37mg/l and 5.60mg/l in all sampling points. These average values are highly surpassed the limits accepted by RSB that stands at 0.3 mg/l.

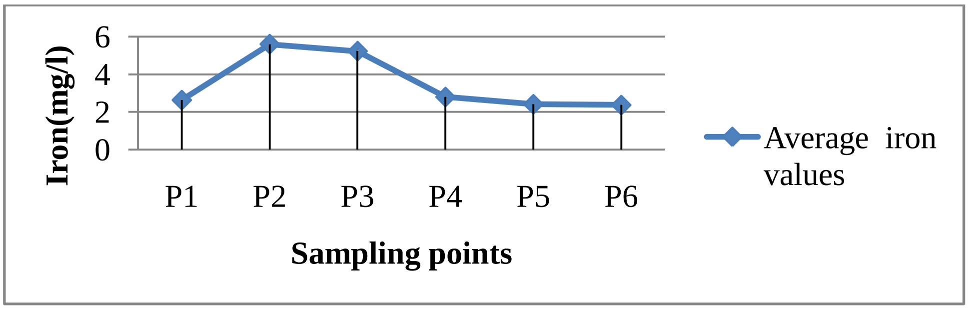

FIGURE 11: Average of iron concentration according to sampling points in Bishya dam

From the graph above, the concentration of iron is higher in sampling points P2 and P3 situated near the plantation of maize and Mulberry respectively.

3.2.2.8 Results from Manganese laboratory test

Laboratory tests for manganese have shown that the concentration level of manganese in Bishya dam varies from 0.14 mg/l to 0.78mg/l in all sampling points. These average values exceeded the limit of RSB standing at 0.1 mg/l.

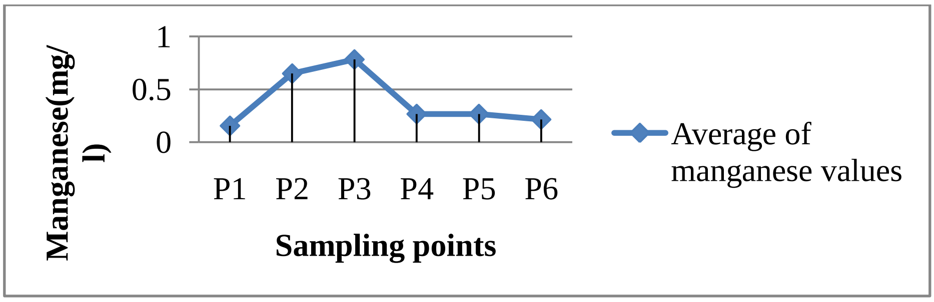

FIGURE 12: Average of manganese concentration according to sampling points in Bishya dam

The graph indicates that the concentration of manganese is increasing in P2 and P3 situated in the areas of Maize and mulberry plantation respectively. This situation means that Bishya dam accommodates the sediments of manganese that are highly soluble in water and their concentration manifest itself during the dry season than rainy season.

3.2.2.9 Results from Chemical Oxygen Demand laboratory test

Laboratory tests for chemical oxygen demand have demonstrated that COD concentration ranged between 46.50 mg/l to 58.41 mg/l in all sampling points. The sampling points P2, P3, P4, and P5 present the average results that are above the limit of RSB (respectively 58.41 mg/l, 52.3 mg/l, 53.4mg/l, and 51.08mg/l); other points P1 and P6 (46.50 mg/l and 49.0 0mg/l respectively), represent average results accepted by RSB guideline which is 50mg/l.

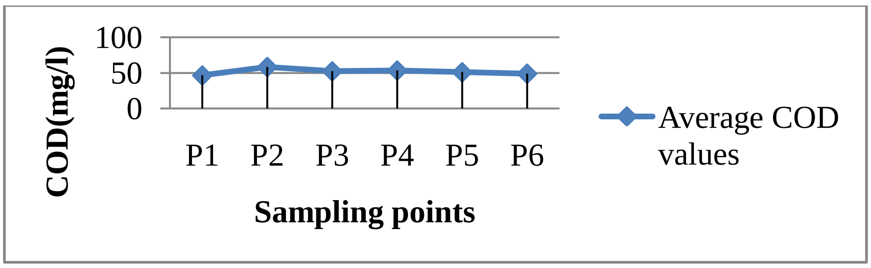

FIGURE 14: Average of chemical oxygen demand concentration according to sampling points

From graph analysis, the COD concentration is high in P2 comparatively to other sampling points. This sampling point P2 is nearing the maize plantation. The high concentration level of COD in Bishya dam makes it polluted. COD is an indicator of organic pollution, which is caused by the inflow of agrochemicals, livestock, and industrial waste that contains elevated levels of organic pollutants.

3.3 Correlation between agricultural practices and water quality from Bishya dam

3.3.1 Demonstration of coefficient of correlation using Linear Regression Model

In order to demonstrate the correlation between agricultural inputs and water quality from Bishya dam, a Linear Regression Model using SPSS statistics with confidence interval of 95% was adopted (Table 2).

TABLE 2
COEFFICIENT OF CORRELATION BETWEEN AGRICULTURAL INPUTS AND WATER QUALITY FROM BISHYA DAM

Sampling sites	P1 N=12	P2 N=12	P3 N=12	P4 N= 12	P5 N=12	P6 N= 12
Coefficient of correlation(r)	r	r	r	r	r	r
PH	-0.25	0.066	0.048	0.300	0.266	-0.109
Turbidity(NTU)	-0.027	-0.132	-0.028	-0.084	0.080	-0.011
Nitrites (mg\L)	0.047	0.010	0.086	0.123	0.095	0.049
Nitrates (mg\L)	0.033	0.064	0.077	0.080	-0.060	0.046
Ammonia Nitrogen (mg\L)	-0.044	0.109	-0.027	-0.047	-0.003	0.134
Phosphate (mg\L)	0.384	-.0536	0.329	-0.312	0.188	0.277
Iron (mg\L)	0.11	0.059	-0.060	0.182	0.093	0.106
Manganese (mg\L)	0.018	-0.077	-0.046	0.051	0.051	0.190
Chemical Oxygen(mg\L)	-0.063	0.012	-0.059	-0.143	0.017	0.106

3.3.2 Correlation between agricultural inputs and water pollution from Bishya dam

The relationship between agricultural practices and water quality from Bishya dam was demonstrated trough Linear Regression Model using SPSS with confidence interval of 95% considering both data from agricultural inputs used by farmers in their respective farm crops as summarized in Table 3, and laboratory results of water samples as indicated in Table 1.

TABLE 3
SUMMARY OF FINDINGS OF AGRICULTURAL ACTIVITIES IN BISHYA WETLAND AND SURROUNDING AREAS

Cooperative	Farm size (Ha)	Crops	Direction towards sampling points	Agricultural inputs	Quantity (kg)
NGIRANKUGIRE	76	Maize	P1	NPK 17*17*17	19000
				Organic manure	380000
				Chlorpyrifos-ethyl	76
SHINGISUKA	59	Maize	P2	NPK 17*17*17	14750
				Organic manure	295000
				Chlorpyrifos-ethyl	59
TURENGERABANA	52	Vegetables	P4	Organic manure	260000
				Urea	4160
				DAP	5200
				Fungicide	52
				Insecticide	52
TURWANYINZARA	51	Sweet potatoes, cassava	P5	Organic manure	357000
HEworks Rwanda Silk Ltd	57	Mulberry	P3	NPK20*10*10	24510

In previous subsection 3.3.1, we have demonstrated the coefficient of correlation between agricultural inputs and water quality from Bishya dam; however all parameters that showed positive relationship were not indicating pollution basing on RSB standards. Therefore, in this section, we highlight the relationship between agricultural inputs and water quality with emphasis on water quality parameters presenting pollution levels comparing to limits set up by Rwanda Standards Board.

The Linear Regression Model results showed that agricultural activities had positive relationship with nitrites (r=0.047), Phosphates (r=0.384), Iron (r=0.11), and Manganese (r=0.018) in sampling point P1. This situation highlights pollution of water in sampling point P1, which is attributed to extensive use of different fertilizers and pesticides in maize farm crop owned by NGIRANKUGIRE Cooperative where there is stream passing through to fall into the bishya dam.

Results indicated also that agricultural activities had positive relationship with nitrites (r =0.010), Iron (r=0.059), and COD (r=0.012) in sampling point P2. This situation highlights pollution of water in sampling point P2, which is attributed also to the use of different fertilizers and pesticides falling into the dam by small stream passing through maize farm crop owned by SHINGISUKA cooperative.

Moreover, results showed that agricultural activities had positive relationship with pH (r=0.048), nitrites (r=0.086), and phosphates (r=0.329) in sampling point P3. This situation highlights water pollution in sampling point P3 attributed to the use of different fertilizers and pesticides reaching into the dam from the stream passing through the mulberry plantations grown by HEworks Rwanda Silk Ltd.

Furthermore, results revealed that agricultural activities had positive correlation with nitrites (r =0.123), iron (r=0.182), and Manganese (r=0.051) in sampling point P4. This situation highlights water pollution in sampling point P4, which is attributed to the use of different fertilizers and pesticides from the farm of vegetables grown by TURENGERABANA cooperative. Considering also the presence of different types of rocks in surrounding lands, Bishya dam accommodates the most abundant sediments from agricultural activities containing iron and manganese that are highly soluble in water and contribute to dam pollution. It also highlights that absence of anti-erosion and ineffective drainage of Bishya wetland contribute to degradation of water quality though excessive level of iron and manganese concentration.

In addition, results from Linear Regression Model showed that agricultural activities had positive relationship with Turbidity (r=0.080), nitrites (r=0.095), Phosphates (r=0.188), iron (r=0.093), manganese (r=0.051), and chemical oxygen demand (r=0.017) in sampling point P5. The situation highlights water pollution in sampling point P5, which is attributed to the use of different fertilizers and pesticides from the farms of cassava and sweet potatoes grown by TURWANYINZARA farming cooperative in its surrounding. Basing on agricultural features of Bishya wetland surrounding areas characterized by absence of anti-erosion and buffer zone, ineffective wetland drainage, and absence of vegetation cover, Bishya dam accommodates the most abundant sediments transported by soil erosion.

Finally, results highlighted that agricultural activities had positive relationship with nitrites (r =0.046), Phosphates (r=0.277), Iron (r=0.106), and Manganese (r=0.190) in sampling point P6. The situation highlights water pollution in the Bishya dam intake (sampling point P6) for water supply systems in NYANZA District. This water pollution comes from the use of different fertilizers and pesticides from different streams falling into the dam from different directions of Maize, mulberry, vegetables, sweet potatoes and cassava farm crops, owned by farmer cooperatives namely NGIRANKUGIRE, SHINGISUKA, TURENGERABANA, TURWANYINZARA, and HEworks Rwanda Silk Ltd. Also the absence of anti-erosion, wetland bank, vegetation cover, and ineffective drainage of wetland, Bishya dam accommodates different dissolved minerals transported by erosion.

IV. CONCLUSION

Agricultural practices in Bishya wetland and surrounding cropland areas characterized by availability of different crops, ineffective drainage, absence of anti-erosion structures, weak management of wetland margins, absence of vegetation covers, use of organic manures, chemical fertilizers and pesticides, and presence of different types of rocks and soils have influenced water quality in Bishya wetland in all sampling points of Bishya dam as the agricultural inputs were positively correlated with water quality parameters. However, the positive relationship does not mean that all selected parameters have manifested pollution, but some of them did according to RSB guidelines. The parameters that presented pollution were nitrites (r=0.047), Phosphates (r=0.384), Iron (r=0.11), and Manganese (r=0.018) in sampling point P1; in sampling point 2, they were nitrites (r=0.010), Iron (r=0.059), and COD (r=0.012); in sampling point 3, they were pH (r=0.048), nitrites (r=0.086), and phosphates (r=0.329); in sampling point 4, they were nitrites (r=0.123), iron (r=0.182), and Manganese (r=0.051); in sampling point5, Turbidity (r=0.080), nitrites (r=0.095), Phosphates (r=0.188), iron (r=0.093), manganese (r=0.051), and chemical oxygen demand (r=0.017); and in sampling point6, parameters that presented pollution were nitrites (r =0.046), Phosphates (r=0.277), Iron (r=0.106), and Manganese (r=0.190). For sustainable wetland management the researcher suggested the following:

- ✓ To create effective anti-erosions in all areas surrounding Bishya wetland
- ✓ To sensitize people using croplands surrounding Bishya wetland to fully respect the minimum of wetland margins (buffer zone) according to the law on wetland protection applicable in Rwanda,
- ✓ To consider the importance of ecological values of wetlands while developing policies for economic development.
- ✓ To introduce mass education in order to make the population understand well the importance of wetland ecosystem functions.
- ✓ To set up water management bodies at cells level
- ✓ The agricultural policy should not only be focused on the increase in production but also the future use of the wetland.
- ✓ Increase awareness in environmental protection and sustainable management of water resources for farmers in bishya wetland.
- ✓ To capture rain water from their houses in order to avoid erosion.
- ✓ Respect the laws governing the use of wetland in Rwanda.

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