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Impact of Agricultural Practices on the Water Quality of Rwakaiha Wetland, Kyegegwa District, Uganda

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Authors' contributions

This work was carried out in collaboration between both authors. Author PK formulated study objectives; searched for related literature; designed the methodology; collected data; and analyzed the data. Author AB formulated the title of the study and objectives; searched for related literature; analyzed the collected data; discussed the findings; proof read the entire manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Wetlands are critical natural resources and perform a range of environmental functions. They are at times prone to degradation either directly or indirectly through anthropogenic activities which are undertaken in their surroundings. The study sought to explore the effects of agricultural practices on the water quality of Rwakaiha wetland, Kyegegwa district. Specifically, the study established agricultural practices undertaken in and around the wetland, and determined the physicochemical parameters of the water samples obtained from the wetland. Cross-sectional and experimental

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research designs were employed to achieve the stated objectives. A questionnaire survey was used to obtain the information concerning the agricultural practices undertaken in and around the wetland, while in-situ and laboratory experiments determined the physicochemical characteristics of the water samples. Results revealed that, crop growing including yams, potatoes and maize, aquaculture and animal rearing were some of the agricultural practices undertaken by the community members in the study area. Apart from Chemical Oxygen Demand (COD) that exhibited elevated levels in the water samples, the pH, temperature, Biological Oxygen Demand (BOD), Electrical Conductivity (EC), turbidity and Total Dissolved Solids (TDS) were all within the permissible limits as compared to World Health Organisation (WHO) standards. All the heavy metals tested were way beyond the permissible levels, presumed to stem from the agricultural practices. It is recommended that awareness be created to members of the community to intensify on the use of organic fertilizers. The government should highly levy taxes on the inorganic fertilizers in order to discourage the over application of the same, since they end up with detrimental environmental effects.

Keywords: Agricultural Practices; Heavy Metals; Wetland Characteristics; Water Quality.

1. INTRODUCTION

Wetlands are critical natural resources in developing countries where they perform a range of environmental functions and provide numerous socio-economic benefits to local communities and a wider population (de Groot et al., 2018). Wetlands are amongst the most productive ecosystems in Sub-Saharan Africa; because of their capacity to store, distribute, filter, and gradually release large quantities of fresh water stock (Xu et al., 2020; Ji et al., 2022; Barakagira & Kateyo, 2006). Wetlands sustain rural livelihoods, particularly in areas with unpredictable rainfall, land scarcity, or uplands with poor water characteristics, and thus low potential for agriculture (Barakagira & Ndungo, 2023; Lamsal et al., 2015; Turyahabwe et al., 2013). Several studies in Southern and Eastern Africa have shown that wetlands and their surrounding catchments support rural livelihood through provision of a wide range of ecosystem services that contribute to human well-being such as nutrition, water supply and purification, climate and flood regulation, and recreational opportunities (Barakagira & de Wit, 2017; Turyahabwe et al., 2013).

Globally, water quality degradation is one of the most persistent, and in most cases, visible signs of human effects varying widely at regional and local scales on the natural environment with the major water pollutants resulting to chemical, physical, and microbial factors originating from industrialized countries (Wang et al., 2015). Surface-water bodies, such as wetlands, streams, lakes, and reservoirs, are extremely susceptible to direct discharge of liquid and solid agricultural waste (Ji et al., 2022). In developing countries, the changes in land use may directly or indirectly be related to traditional pollution problems, such as sewage discharge, application of pesticides and insecticides, which may heavily degrade the water resources, particularly those near the urban industrial centers and intensive agricultural areas (Wang et al., 2015), thereby altering their ecological landscape (Norman et al., 2005). Proportionately, environmental problems like increase in waterborne related diseases have been as a result of water quality degradation (Osibanjo & Adie, 2007). Jiang et al. (2018) states that, cities in most developing countries generate on the average 30-70mm^3 of wastewater per person per year due to improper wastewater treatment facilities, and that the effluents are often discharged into surface water sources, which are receptacles for domestic and industrial wastes, acting as the major contributors to wastewater pollution. Water quality problems comprise of the physical, chemical and biological characteristic of a watershed, which reverberate from human-induced activities of organic pollution, eutrophication, acidification, toxic contamination, temperature changes due to indirect thermal discharges (Ding et al., 2015). Africa is the second largest continent in the world and it is characterized with some fresh water and biodiversity. Unfortunately, it is only composed of 9% of the global renewable water resources to support 15% of the global population. Lack of water in Africa is further attributed to insufficient treatment and discharge of water and wastewater, particularly with the ever-increasing population and urbanization (Wang et al., 2014). The discharge of untreated and inadequately treated effluents onto the drainage areas has adverse effects on the physicochemical and bacterial composition of the water as well as soils (Amenu, 2014). Hawumba (2017), indicated that; in Uganda the leading causes of water quality impairment is excessive nutrient (nitrogen and phosphorus) loading to the surface water bodies and ground water. The authors further add that, whereas nitrogen is of paramount importance for causing eutrophication in marine ecosystems, phosphorous is the limiting nutrient in freshwater ecosystems. Ding et al. (2015) state that understanding the relationship between land use and water quality helps to identify primary threats to water quality and able to plan and institute relevant measures to minimize pollution loadings.

In Uganda, wetland degradation is one of the most severe and widespread environmental problems due to improper agricultural waste disposal as well as unscrupulous farming activities causing water pollution and consequent degradation of the natural vegetation and the soil resource. The unregulated discharge of untreated agricultural waste water that is produced via runoff after spraying from different source points such as agricultural fields are some of the sources of water resources degradation (Alikhani et al., 2021). Despite government legislation that seeks to protect or ensure sustainable utilization of wetlands in Uganda including Rwakaiha wetland in Kyegegwa district, they have been encroached on through many anthropogenic activities like agriculture (Barakagira and de Wit, 2017; Baguma and Barakagira, 2023). The use of agrochemicals may result into adverse effects on the water quality of the wetlands, which the current study seeks to address. This research project is hinged on two objectives; i. To establish agricultural practices taking place in and around Rwakaiha wetland, Kyegegwa District; and ii. To determine the physicochemical parameters of water samples from Rwakaiha wetland, Kyegegwa district.

2. METHODOLOGY

2.1 Research Design

This study employed both experimental and cross-sectional research designs. Information about the agricultural activities carried out around the Rwakaiha wetlands was collected using the questionnaire survey. Information concerning the water quality from Rwakaiha wetlands was determined by conducting experimental analyses on the collected water samples in the laboratory. The physicochemical parameters were then determined and analyzed. Rwakaiha wetland was selected because of the unregulated agricultural activities that are being practiced around the wetland.

2.2 Sampling Strategy

Field sampling of the water samples for water quality analysis was carried out within the wetland. Water samples were collected in triplicates. Some of the samples were collected at the beginning of the wetland (R1), the other in the middle of the wetland (R2), and lastly at the end of the wetland (R3). At each sampling location, the samples were collected in Duran sampling bottles for the determination of pH, electrical conductivity, total suspended solids, selected heavy metals, nitrates, sulphates, biochemical oxygen demand and chemical oxygen demand. These constituted the major parameters used to measure the degree of pollution of the water resource. All the samples were preserved at 4ºC using a sample cooler box and transported to the laboratory for chemical analysis.

For the case of the agricultural activities carried out around the wetland, out of about 16,000 people present in the area, 100 respondents were regarded as the target population of people practicing agriculture. A sample size of 80 respondents was determined using the Yamane formula (n= sample size, N= Target population, e= standard error).

$$n = \frac{N}{1 + N(e^2)}$$

$$n = \frac{100}{1 + 100(0.05^2)}$$

$$n = 80$$

The eighty respondents were randomly selected from the areas surrounding the Rwakaiha wetland. Each selected respondent was then briefed and informed of the purpose of the study. The respondents were also assured of confidentiality and anonymity. A questionnaire was then administered to the selected senior member of the household.

2.3 Analytical Procedures and Measurements

The physicochemical characteristics were determined using an electrochemical analyzer, and metals were quantified spectrophotometrically following standard approved methods.

2.3.1 Determination of inorganic anions in the water samples

The inorganic anions including nitrates and sulphates, were determined by a standard HACH procedure using the DR 1900 spectrophotometer and DRB 2000 digester as described in the HACH procedure manual that has been specifically designed for testing a wide range of physical and chemical water quality parameters, including total nitrogen and sulphates.

In order to collect the Nitrate concentrations' data in the water samples, sample preparation and Nitrate analysis using UV-Vis spectrophotometer was used. 1g of Salicyclic acid was mixed with 5M concentrated Sulphuric acid. The mixture of Salicyclic acid and concentrated Sulphuric acid was added to 5ml of each sample and shaken. The resultant filtrate mixture was be left to stand for 20 minutes for color development, that is to say, from colorless to yellow. 20ml of sodium hydroxide was then added to the solution of each sample so as to neutralize the pH. 2ml of each sample were then poured into the cuvettes and placed in the compartment of the UV-Vis spectrophotometer for nitrate determination and procedures were followed on blank solution to act as the control experiment. This was in accordance to Rao & Puttanna (2000).

For the dissolved sulphate, the turbidimetric method, Hach Method 8051, using the Hach 'Spectrophotometer DR/2000' with SulfaVer 4 powder pillows were used to collect data for the sulfate concentrations (Hach, 2012). Concentrations were reported as mg/L $SO4^{2-}$, dissolved (Stednick, 1991).

2.3.2 Determination of chemical oxygen demand and biochemical oxygen demand

Chemical Oxygen Demand was determined by a standard HACH procedure using the DR 6000 spectrophotometer and DRB 200 digester as described in the HACH procedure manual that has been specifically designed for testing a wide range of physical and chemical water quality parameters. Biochemical oxygen demand was analyzed using a BOD_5 day test kit. This was used for digestion and monitoring oxygen changes.

2.3.3 Determination of pH, total dissolved solids, salinity, turbidity, and electrical conductivity

The pH, TDS, Salinity and Electrical conductivity were analyzed using an electrochemical analyzer (Consort C6010), Turbidity was analyzed spectrophotometrically using a Hach Turbidity Meter.

2.3.4 Determination of heavy metals in the water samples

Water samples were directly filtered and aspirated into the Atomic Absorption Spectrophotometer for determining Arsenic (As), Copper (Cu), Iron (Fe), and Cobalt (Co). Chromium (Cr) was determined calorimetrically using a UV-visible spectrophotometer (Genesys10s).

3. RESULTS AND DISCUSSION

The current study was undertaken in and around Rwakaiha wetland, Kyegegwa district. It was aimed at determining the agricultural activities undertaken by community members, that may have an effect on quality of the water in the said wetland, and also to determine the physicochemical characteristics of the water samples obtained from the wetland.

3.1 Demographics of the Respondents

Majority of the respondents (53%) were males, and most of them (75%) were aged 31 years and above. Almost three-quarters (74%) of the respondents never studied beyond the primary level of education. This is probably why majority (84%) of the respondents are peasants as revealed in Table 1, and are able to utilize environmental resources like agriculture for their livelihoods. Practicing agricultural activities around wetlands are likely to have some deleterious effects on the quality of the water. This is in agreement with authors like Singha & Pal (2023) and Atiim et al. (2022) who state that erosion from farmlands located near wetlands may contain some chemicals applied on the crops which may alter the parameters of the water and hence causing detrimental effects to wetlands' sustainability.

3.2 Agricultural Practices Undertaken Around the Wetland

The study revealed a host of agricultural activities being practiced around the wetlands. The activities mainly included crop growing

(43%), that is; yams, potatoes and maize. Crop growing was followed by aquaculture (24%) that involve tilapia (*Oreochromis*), animal rearing (17%) included sheep, goats, and cattle, and forestry (16%) that involve planting of pine (*Pinus*) as observed in Fig. 1.

Crop growing and aquaculture were the dominant activities practiced, bearing in mind that, majority of the respondents were peasants. Application of agrochemicals in the gardens where crops are grown could be one of the avenues through water sources degradation, especially when the chemicals are applied in excess (Rad et al., 2022). The use of the fish feed concentrates that contain different ingredients may also contribute to the lowering of the water quality, where fish farming is practiced. The findings are in agreement with some authors like Osinuga et al. (2023) and Tang et al. (2021) who posit that modern agriculture heavily relies on the use of agrochemicals that have the potential of degrading the surrounding water sources. In addition, El-Kady et al. (2022) and Yanuhar et al. (2022) posit that some commercial probiotics used as water additives and other inedible suspended solids present in fish feeds contribute to changes in the water quality.

3.3 Physicochemical Characteristics of the Water Samples from the Wetland

Water samples were collected from different points of the wetland during the dry season. The points included; where the wetland was in proximity of the agricultural activities (R1), then from the middle of the we land (R2), and from the extreme end of the eland (R3). Other water samples were collected from a neighbouring wetland where there are no agricultural activities being practiced as a control. The samples were tested for pH, temperature, BOD, EC, Turbidity, TDS, and COD. The results obtained were then compared with the WHO standards as shown in Table 2.

The results obtained revealed that all the parameters tested, including, pH, temperature, BOD, EC, turbidity, sulphates, and TDS had values that were within the WHO permissible limits. Only the average COD and nitrate concentration values obtained, 163.15 mg/L and 24 mg/L respectively, were above the WHO permissible limits. This was probably because of the presence of the high organic matter present in the wetland that required a lot of oxygen to be broken down. In addition, agricultural runoff is believed to culminate into high COD and nitrate concentration in the wetlands, due to presence of nitrates and ammonia present in fertilizers that were presumed to have been used in excess during the agricultural practices. Authors like Ameso et al. (2023) and Jin et al. (2017) are in agreement with the findings, when they document that the elevated COD in wetlands is as a result of increased organic pollution, either from the decaying organic matter from the wetland or surrounding agricultural lands. Cui et al. (2020) affirms that the presence of nitrogen and ammonia from the agricultural runoff contributes to increased COD and nitrate concentration in the wetlands.

In addition, water samples were tested for the presence of the heavy metal concentration. The heavy metals that were tested included; Arsenic (As), Chromium (Cr), Cobalt (Co), and Copper (Cu). The results were compared with the WHO permissible levels as shown in Table 3.

Table 1. Socio-demographic characteristics of the respondents (Questionnaire survey, 2023)

Variable		**N**	**Percentage**
Gender	Male	42	53
	Female	38	47
Age (Years)	<20	1	1
	21-30	19	24
	31-40	25	31
	41-50	26	33
	>50	9	11
Level of Education	No formal Education	27	34
	Primary	32	40
	Secondary	14	17
	Post-Secondary	7	9
Occupation	Peasant	67	84
	Businessman	11	14
	Civil Service	3	2

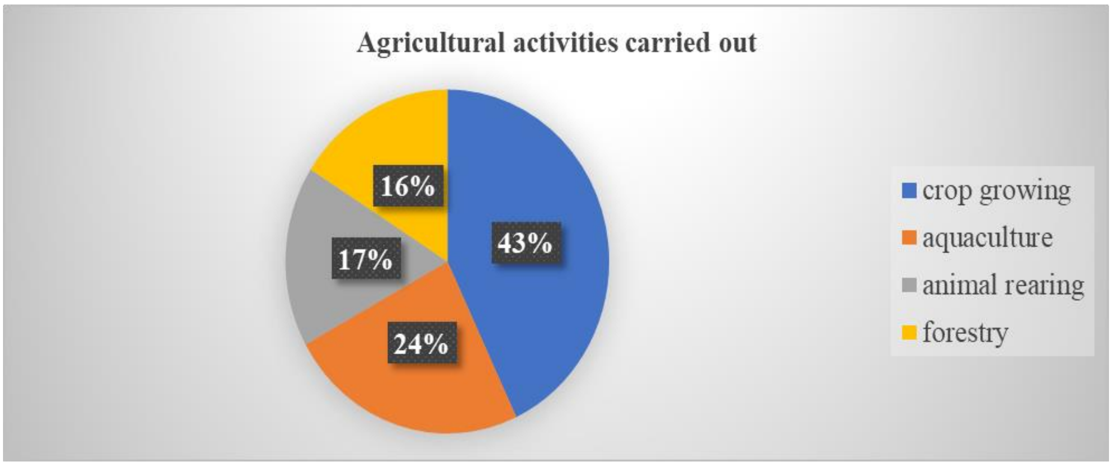

Fig. 1. Agricultural Practices carried out around Rwakaiha wetland (Primary data, 2023)

Table 2. Physicochemical characteristics of the water samples (Primary data, 2023)

Sample	pH	Temp/^{0}C	BOD (ppm)	EC (μs/cm)	Turbidity (ppm)	TDS (mg/L)	COD (mg/L)	Nitrates (mg/L)	Sulphates (mg/L)
R1	6.48	23.70	3.93	147.97	167.67	78.93	165.07	26	0.87
R2	6.86	23.70	4.23	130.70	160.33	68.43	89.76	25	0.95
R3	5.59	23.60	3.92	51.80	119.67	26.9	234.61	21	1.10
Average	6.31	23.67	4.03	110.16	149.22	58.09	163.15	24	1.00
Control Wetland	5.80	26.70	2.91	60.20	87.14	25.76	40.98	9	0.85
WHO standards	6.0-8.0		50	1500	300	1200	100	10	2

Table 3. Heavy metal concentration in the water samples (Primary data, 2023)

Sample	Heavy Metal Concentration (mg/L)			
	As	Cr	Co	Cu
R1	22.45	74.25	17.00	8.17
R2	8.89	38.20	17.57	10.69
R3	25.17	148.00	45.61	30.80
Average	18.84	86.82	26.73	16.55
WHO Standards	0.20	1.00	1.00	1.00

The heavy metal concentration of all the metals tested from the water samples obtained from the wetland were above the permissible WHO standards. This could have resulted from the agricultural runoff and household effluents from the neighboring communities of the wetland. Therefore, there is presence of high amounts of As, Cr, Co, and Cu in the wetland. The findings concerning the elevated levels of the heavy metals are in congruent with the documentations of other authors like Li et al. (2022) and Aarif et al. (2023), which state that wetlands located between the agricultural lands and industries are subject to inputs of heavy metals coming from the agricultural inputs and chemicals carried in the effluents from the factories. Zhao et al. (2021) states that wetland nutrient enrichment especially from inorganic manure applied to agricultural gardens may get eroded into wetlands especially during the rainy seasons, leading to an increase in the concentration of heavy metals. In addition, Pule & Barakagira (2022) asserts that the presence of heavy metals in water sources are mainly as a result of anthropogenic activities like mining which are practiced in their vicinity.

4. CONCLUSION AND RECOMMENDATIONS

A host of the agricultural activities are carried out around the Rwakaiha wetland, Kyegegwa district.

The activities have insignificant effect on the physicochemical properties of the water in the wetland. However, there are elevated levels of heavy metals including As, Cr, Co, and Cu, probably because of applications of inorganic fertilizers (NPK) in the surrounding agricultural fields.

Farmers who live and practice agriculture around the wetlands are encouraged to mainly use organic fertilizers (manure) to avoid further contamination of the wetland water resulting from agricultural runoff. Also, community members are encouraged to properly dispose of the domestic effluents other than leaving them to just flow into the wetland.

The government should sensitize community members to mainly use organic fertilizers for their agricultural practices and also put up some disincentives like high taxes on the organic fertilizers to discourage their over application.

Similar research should be conducted in the study area, during the wet season to ascertain whether different results or elevated levels of the parameters studied are obtained.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

FINANCIAL DISCLOSURES

This research was privately funded.

DATA AVAILABILITY

The data presented in the manuscript is available on request.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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