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ORIGINAL ARTICLE

# Spatial variability of water quality for rice irrigation in Rusurirwamujyinga Sub-catchment

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*The quality of water used for irrigation is essential for yield. Quantity of crops, maintenence of soil productivity. However, irrigation water can also have profound effects on soil and plant health. If poorly managed, irrigation water can cause decreased crop yields and land degradation. This is as a result of irrigation induced problems such as salinity and water-logging. This study was carried out at the Rusurirwamu jyinga rice irrigation scheme in Rwanda to assess spatial water quality variability and its response on growth of irrigated rice. Physico-chemical parameters such as Temperature ($T^oC$), Electrical Conductivity ($EC_W$), Total Dissolved Solid (TDS), Hydrogen ion concentration (pH), Sodium ($Na^+$), Potassium ($K^+$), Calcium ($Ca^{++}$), Magnesium ($Mg^{++}$), Boron ($B^-$), Chloride ($Cl^-$), Nitrate ($NO_3^-$), Sulphate ($SO_4^{--}$), Bicarbonate ($HCO_3^-$), Carbonate ($CO^{--}$), Copper ($Cu^{++}$), Zinc ($Zn^{++}$) were analyzed at upstream, middle and downstream of the river running through the rice scheme. The statistical tools used to analyze data were mainly descriptive and inferential statistics. The general ANOVA and LSD at ($P < 0.05$) were used to estimate the significant levels of water quality between the three stream positions. The results show that there is significant of water quality as it moves the three stream positions within the rice irrigation scheme. Due to the pressure of human encroachment surrounding the irrigation scheme, from upstream to downstream, several pollutants, sediment loss, dam siltation along the river and canals were observed as signals of resource degradation in the catchment. Rusurirwamujyinga sub-catchment needs to be sustained by reducing the negative impact which causes water pollution. The use of Best Management Practices (BMPs) to reduce agriculture's impact on water quality while enhancing agricultural production in the irrigation scheme will be the best way of soil and water management by ensuring quality of water to irrigate rice*

***Key words**: Irrigated rice; Rusurirwamujyinga Sub-catchment; Spatial; Water quality*

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## INTRODUCTION

In a broad term, water quality refers to the physical, biological and chemical states of the water body. Water quality is important not only because of its linkage to the availability of water for various uses and its impact on public health, but also because water quality has an intrinsic value. The quality of life is often judged on the availability of pristine waters. The water quality used for irrigation is essential for the yield and quantity of crops, maintenance of soil productivity, and protection of the environment. For example, the physical and mechanical properties of the soil, soil structure (stability of aggregates) and permeability are very sensitive to the type of exchangeable ions present in irrigation waters [1]. Defining background conditions of water quality is important for water and land managers in assessing the effects of human activities, such as land use, on water resources [2].

It has been recognized that the quality of water changes continuously and many different anthropogenic factors and activities in a watershed via point sources, as wastewater treatment facilities, and non-point sources, as run-off from farm land and urban area affect the quality of receiving waters [3]. A strong relationship between stream flow and stream-water chemistry at different spatial scales has been identified for rivers and streams [4]. Huang and Foo [5] claim that engineering and management modifications in a river system may change the water quality characteristics of the river.

Agriculture demands more water than any other single activity, requiring 69% of the world's water supply [6]. In Rwanda, of all the amount of water used for different purposes, 94 % is used for agriculture [7]. In many countries, efforts to raise levels of agricultural production through increases in cultivated land, cropping intensity and yields have led to a greater dependence on irrigation. Where irrigated agriculture is developed, 90% of water is used during the dry season. Water used for irrigation can vary greatly in quality, depending upon the type and quantity of dissolved salts. Salts are present in irrigation water in relatively small but significant amounts. They originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum and other slowly dissolved soil minerals [8]. Good management of irrigated land is therefore an important factor in ensuring sustainable production [9]. The major constraints to rice production in Rwnda include, the water regulation in irrigation and drainage system, these lead to the shortage of quantity and degradation of the quality among others [10, 11].

This is particularly burdensome in Rusurirwamujyinga rice irrigation scheme, where rice production seems to be lowered due to lack of water management.

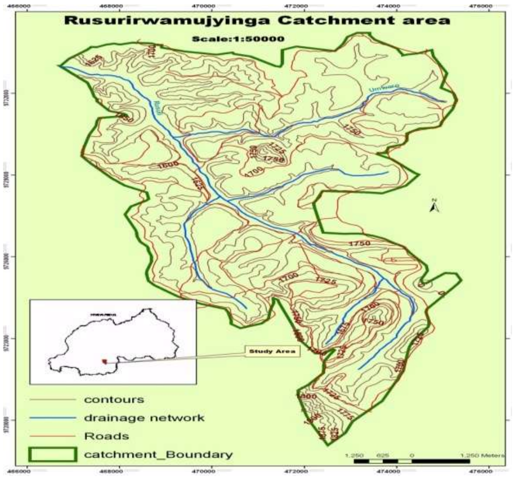
Phil *et al.* [12] noted that irrigation water is necessary for a productive rice crop, and poor quality water can cause soil-related problems that negatively impact rice production. Some of the predominant soil-related problems that affect rice include salinity (high soluble salts), zinc deficiency, phosphorus deficiency and excessive sodium, which cause poor physical soil conditions. Yutaka [13] reported irrigation water quality guidelines for paddy rice system in Japan where heavy metals are, of course, a concern for the health of consumers. Hoffman et al. [14], Guy [15] and Harvand [16] highlighted the guidelines for irrigation water quality standard and salinity management strategy for enhancing agriculture production. Nevertheless, water quality testing is an important step in diagnosing existing problems and identifying potential problems.

This study assessed spatially the quality of water used to grow rice in Rusurirwamujyinga irrigation scheme. Physico-chemical parameters such as Temperature ($T^oC$), Electrical Conductivity ($EC_w$), Total Dissolved Solid (TDS), Hydrogen ion concentration (pH), Sodium ($Na^+$), Potassium ($K^+$), Calcium ($Ca^{++}$), Magnesium ($Mg^{++}$), Boron ($B^-$), Chloride ($Cl^-$), Nitrate ($NO_3^-$), Sulphate ($SO_4^{--}$), Bicarbonate ($HCO_3^-$), Carbonate ($CO^{--}$), Copper ($Cu^{++}$), Zinc ($Zn^{++}$) were analyzed at upstream, middle and downstream of Rusurirwamujyinga running through the rice irrigation scheme. In addition, Gen Stat 12th used in statistical analysis, both descriptive and inferential statistics. The general ANOVA and LSD at ($P < 0.05$) were used to estimate whether there is a significant difference of water quality within the streams positions.

## Materials and Methods

### Study area

Rusurirwamujyinga Sub-catchment occupies an area of 67.171 $Km^2$ and has population of 84,313 people who reside within Rusatira, Ruhashya, Rwaniro and Kinazi sector of Huye District in the Southern Province of Rwanda, upper Mwogo catchment area, which plays major role in regulation of water flow to Nile basin. Geographically, it lies between longitudes 29° 40' 0" and 29° 48' 0" East of Greenwich and between latitude 2° 23'50" and 2° 31'58"S South of the Equator. Altitude varies between 1200-1700 m above sea level and the average annual precipitation is 1171mm. The sub-catchment area is drained by Rusurirwamujyinga River which has several tributaries such us Gasuma, Akogo, Gahama, Gatare, Nyakagezi and Umwaro. The whole drainage area covers about 608 ha and the rice irrigated area covers about 400 ha. ( see the map of the study area depicted for the map of Rwanda).



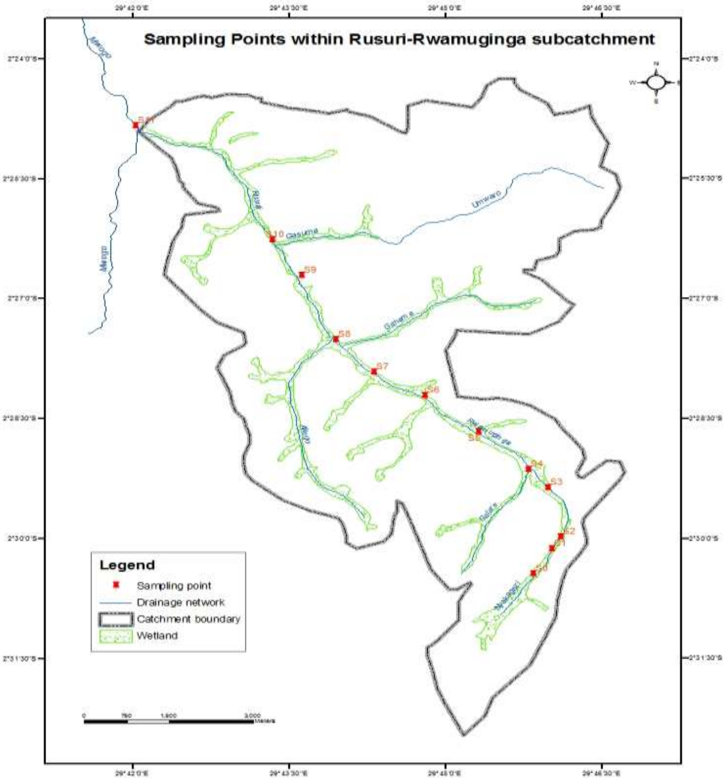
*Map of the study area*

### Sampling method

Three homogenous zones were demarcated from the study area, namely, the lower zone, the middle zone and the upper zone according to drainage distribution and topography. Samples were taken at different points of the rice irrigation scheme. The sampling sites started from $S_0$ in-let dam (not irrigated) and ended at $S_{11}$ also (not irrigated), which is at Mwogo, the main river in the catchment area.

**Table1: Location of the sampling points within the study area**

| Nº | Sub-catchment area | Sampling point | Geographical Coordinate | Physical Observation |
|---|---|---|---|---|
| 1 | Up stream | So | S: 2° 30’36.4”<br>E: 29° 45’52.9” | Inlet dam |
| 2 | | S1 | S: 2° 30’17.4”<br>E: 29° 46’03.8” | Outlet dam |
| 3 | | S2 | S: 2° 30’08.3”<br>E: 29° 46’08.7” | Bandagure bridge |
| 4 | | S3 | S: 2° 29’31.6”<br>E: 29° 46’01.7” | Mugogwe bridge |
| 5 | | S4 | S: 2° 29’15.8”<br>E: 29° 45’50.2” | Agatare stream |
| 6 | Middle stream | S5 | S: 2° 28’49.8”<br>E: 29° 45’21.8” | Musasu bridge |
| 7 | | S6 | S: 2° 28’22.3”<br>E: 29° 44’50.7” | Kiruhura bridge |
| 8 | | S7 | S: 2° 28’04.6”<br>E: 29° 44’21.3” | Ruhashya stream |
| 9 | | S8 | S: 2° 27’40.6”<br>E: 29° 43’59.3” | Bweramana bridge |
| 10 | Down stream | S9 | S: 2° 26’52.5”<br>E: 29° 43’39.8” | Gahama stream |
| 11 | | S10 | S: 2° 26’25.6”<br>E: 29° 43’22.5” | Agasuma stream |
| 12 | | S11 | S: 2° 25’00.3”<br>E: 29° 42’03.6” | Enter Mwogo River |



*Map of the sampling points*

## Sample collection and preservation

The water samples were taken for a period of nine months every 25th day of the month from August 2010 to April 2011 in order to standardize the sampling time. Depending on the stream positions (upstream, middle stream and downstream) and the seasonal variability of the country, sampling was frequently done two times per season in the dry season (August and September), moderate season (November and January) and rainy season (March and April). Plastic bottles were used for collecting water samples. These were washed with phosphorus free detergents and rinsed with 1M HCl 24 hours before sample collection. They were again rinsed twice with sample water before final sample collection. The plastic bottles were labeled properly for identification according to the point number before sample collection to avoid confusion of samples. Samples collected from study area were carefully transported to the laboratory and kept in a refrigerator at 4°C before analysis [17, 18].

**Table 2:Water sample preservation and storage before analysis in laboratory.**

| **Variable** | **Recommended container** | **Preservative** | **Max. Permissible storage time** |
|---|---|---|---|
| pH | polyethylene | None | 6 hrs |
| $EC_w$ | polyethylene | cool 4 °C | 24 hrs |
| $NO_3^-$ | Polyethylene | cool 4 °C | 24 hrs |
| $SO_4^{--}$ | Polyethylene | cool 4 °C | 7 days |
| $Cl^-$ | Polyethylene | cool 4 °C | 7 days |
| $B^-$ | Polyethylene | cool 4 °C | 6 months |
| $HCO_3^-$ | Polyethylene | cool 4 °C | 24 hrs |
| $CO_3^{--}$ | Polyethylene | cool 4 °C | 24 hrs |
| $Ca^{++}$ | Polyethylene | cool 4 °C | 7 days |
| $Mg^{++}$ | Polyethylene | cool 4 °C | 7 days |
| $K^+$ | Polyethylene | cool 4 °C | 7 days |
| $Na^+$ | Polyethylene | cool 4 °C | 7 days |
| $Cu^{++}$ | Polyethylene | 2 ml Conc. $HNO_3$/L sample | 6 months |
| $Zn^{++}$ | Polyethylene | 2 ml Conc. $HNO_3$/L sample | 6 months |

**Source:** APHA [24] and Bartram and Ballance [25]

## Analysis

Natural waters are never pure; they always contain varying amounts of dissolved gases and solids (Shaki and Adeloye, 2006). The major ionic species in most natural waters were analysed in irrigation scheme and compared with water quality standards for irrigation set by FAO, US-EPA and many other scholars worldwide. In data analysis, the following points were considered: The water quality variability within the space from upstream to downstream); the physical parameters data directed measured in the field such as T°C, pH, $EC_w$ and TDS and the variation of ions among others anions and cations within the irrigation scheme. Some parameters were tested such as Temperature (T°C), Electrical Conductivity ($EC_{w,}$), Total Dissolved Solid (TDS), Hydrogen ion concentration (pH), Sodium ($Na^+$), Potassium ($K^+$), Calcium ($Ca^{++}$), Magnesium ($Mg^{++}$), Boron ($B^-$), Chloride ($Cl^-$), Nitrate ($NO_3^-$), Sulphate ($SO_4^{--}$), Bicarbonate ($HCO_3^-$), Carbonate ($CO^{--}$), Copper ($Cu^{++}$), Zinc ($Zn^{++}$).

The pH, Temperature, $EC_w$ and TDS were determined directly on-site electrometrically using digital pH and digital conductivity meter (Model Hanna Conductivity meter). Calcium ($Ca^{++}$), Magnesium ($Mg^{++}$), Copper ($Cu^{++}$) and Zinc ($Zn^{++}$) were analysed by atomic absorption spectrophotometer (Model Perkin Elmer, Analyst 200). Sodium ($Na^+$), Potassium ($K^+$), also cations elements were determined by flame photometer (Models PFP7). Bicarbonate ($HCO_3^-$), carbonate ($CO^-$) were determined by acidimetric titration method while chloride ($Cl^-$) was determined by argentometric titration method. Boron ($B^-$) and nitrate ($NO_3^-$) were determined by calorimetric method whereas sulphate ($SO_4^{--}$) was analyzed turbid metrically.

## RESULTS AND DISCUSSION

The study used laboratory techniques to extract information about the quality of water used in Rusurirwamujyinga irrigation scheme. The results of water quality variability within streams of the study area are presented statistically by Gen Stat 12th Edition software and Excel spreadsheet. The variation of the quality of water was assessed by considering upstream samples (So, S1, S2, S3 and S4), middle Stream (S5, S6, S7 and S8) and downstream (S9, S10 and S11). The results are summarized (Table 3). Results from stream variation and their replication (ANOVA table) are presented (Table 4).

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **STDEV** | 0.82 | 0.24 | 29.99 | 20.25 | 1.54 | 4.87 | 8.44 | 0.02 | 0 |
| | **Median** | 23.95 | 7.07 | 80.65 | 110.35 | 2 | 15 | 9.5 | 0.09 | 0 |
| **Down stream** | **Mean** | 23.8 | 7.01 | 75.9 | 108.55 | 2.7 | 15.55 | 13.01 | 0.09 | 0 |
| | **Max** | 25.3 | 7.39 | 111 | 150.6 | 8.1 | 30 | 32 | 0.15 | 0 |
| | **Min** | 22.5 | 6.49 | 22.3 | 75.1 | 1.3 | 10 | 1.2 | 0.06 | 0 |
| | **STDEV** | 1.67 | 0.17 | 32.33 | 19.3 | 1.24 | 1.27 | 9.14 | 0.14 | 0 |
| | **Median** | 24.2 | 7.14 | 76.75 | 111.2 | 2.2 | 11 | 15 | 0.15 | 0 |
| **Middle stream** | **Mean** | 24.45 | 7.17 | 80.83 | 110.75 | 2.65 | 11.16 | 13.93 | 0.19 | 0 |
| | **Max** | 28 | 7.6 | 140 | 142.5 | 6.5 | 14 | 32 | 0.5 | 0 |
| | **Min** | 21.5 | 6.88 | 37.6 | 74.8 | 1.5 | 9 | 0.9 | 0 | 0 |
| | **STDEV** | 1.33 | 0.25 | 25.98 | 16.59 | 0.98 | 1.68 | 3.98 | 0.11 | 0 |
| | **Median** | 21.55 | 7.07 | 76.3 | 101.95 | 1.85 | 9 | 9.5 | 0.07 | 0 |
| | **Mean n=30** | 21.52 | 7.02 | 75.45 | 104.7 | 2.12 | 9.16 | 9.76 | 0.09 | 0 |
| **Up stream** | **Max** | 24 | 7.63 | 116 | 147.7 | 5.2 | 14 | 19 | 0.5 | 0 |
| | **Min** | 19.1 | 6.24 | 37.9 | 76.6 | 1.1 | 7 | 4 | 0 | 0 |
| | **Parameter** | T° (°C) | pH | TDS (ppm) | $EC_w$ (µs/cm) | $NO_3^-$ (mg/L) | $SO_4^{--}$ (mg/L) | $Cl^-$ (mg/L) | $B^-$ (mg/L) | $HCO_3^-$ (mg/L) |
| | **No** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 2.75 | 1.06 | 6.68 | 2.6 | 0.044 | 0.027 |
| 0 | 4.6 | 2.85 | 2.8 | 11.25 | 0.017 | 0.014 |
| 0 | 5.18 | 2.6 | 7.12 | 6.91 | 0.037 | 0.022 |
| 0 | 11.8 | 3.88 | 18.8 | 12.5 | 0.124 | 0.084 |
| 0 | 1.55 | 0.16 | 1.01 | 4.6 | 0.003 | 0 |
| 0 | 2.87 | 1.11 | 5.99 | 2.11 | 0.042 | 0.02 |
| 0 | 6.04 | 3.17 | 2.3 | 6.92 | 0.016 | 0.019 |
| 0 | 6.57 | 3.05 | 6.03 | 7.36 | 0.036 | 0.022 |
| 0 | 14.2 | 5.66 | 21.6 | 12.5 | 0.117 | 0.061 |
| 0 | 1.75 | 0.92 | 1.01 | 4.6 | 0 | 0 |
| 0 | 1.86 | 1.03 | 5.4 | 1.48 | 0.037 | 0.022 |
| 0 | 6.37 | 3.08 | 1.95 | 5.03 | 0.038 | 0.018 |
| 0 | 6.9 | 2.64 | 4.7 | 5.58 | 0.047 | 0.023 |
| 0 | 12 | 4.44 | 18.9 | 10 | 0.124 | 0.095 |
| 0 | 4.4 | 0.14 | 1.01 | 2.6 | 0.007 | 0 |
| $CO_3^{--}$ (mg/L) | Ca $^{++}$ (mg/L) | $Mg^{++}$ (mg/L) | $K^+$ (mg/L) | $Na^+$ (mg/L) | $Cu^{++}$ (mg/L) | $Zn^{++}$ (mg/L) |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 |

**Table 3: The Streams Variability of Irrigation Water Quality**

***Values of all parameters are in mg/L except pH, Temperature (°C), Total TDS (ppm) and ECw (μs/cm)***

The chemical composition of groundwater and surface water is related to the solid product of rock weathering and changes with respect to time and space. Therefore, the variation on the concentration levels of the different hydro-geochemical constituents dissolved in water determines its usefulness for domestic, industrial and agricultural purposes. However, the use of water for any purpose is guided by the standards set by the FAO, UNESCO, WHO and other related agencies [19]. In this study, the results of the analysed chemical parameters were correlated with those of the FAO [7].

The stream's water quality parameters show mean results of parameters measured in the upstream, middle-stream and downstream sections (Table 3). Several parameters (T°, pH, TDS, ECw, $Cl^-$, $B^-$, $Na^+$, $Mg^{++}$) were found increasing more in the middle stream than in the upstream and downstream sections. The parameters ($Ca^{++}$, $Cu^{++}$, $Zn^{++}$) were high in the upstream while $NO^-_3$, $SO^{--}_4$ and $K^+$ were found to be higher in the downstream section. These measurements show inequitable distribution of physico-chemical parameters within the irrigation scheme due to various encroachment activities surrounding the irrigation scheme. Obiefuna and Sheriff [19] emphasized the same issue in their study of" Assessment of Shallow Ground Water Quality of Pindiga Gombe Area, Yola Area in Nigeria". They found out that the geochemical concentrations vary from one settlement to the other depending on the local geology of the area and other human related factors. The temperature has direct effect on certain chemical and biological activities of the organism in aquatic media [20]. The water temperature in middle stream ranged between 21.5 and 28°C. The high temperature in the middle stream is related to several human activities compared to up and downstream sections such as agriculture under pressure, brick making, and deforestation on the hillside bordering middle stream. The biophysical profile changes dramatically in the middle stream, hence TDS and $EC_w$ were concentrated more here than up and downstream and once increasing $EC_w$ and TDS, these parameters are dependent each on other. Emamgholizadeh [1] plotted

Electric conductivity and Total Dissolved Solid in Kopal River, Iran. He concluded that reduced flows can cause accelerated increases of Total Dissolved Solids (TDS) concentrations and Electric Conductivity ($EC_w$) of the river. The same scenario was observed in the study area where stream flows seemed to be reduced in middle stream than upstream and resulted in the soaring of Electric Conductivity and Total Dissolved Solids.

Water pH regulates aquatic chemistry and can impact water use and habitat. The normal pH range for irrigation water is from 6.5 to 8.4 [1]. A pH above 8.5 is often caused by high bicarbonate ($HCO_3^-$) and carbonate ($CO^{--}_3$) concentrations, known as alkalinity. High carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution. This alkaline water could intensify sodic soil conditions [21]. The behaviour of pH in middle stream ranged between (6.88-7.6) with an average of 7.17. This mean that pH has a tendency of floating on acid and alkalinity from upstream to downstream and because of unavailability (under limit of detection) of carbonate and bicarbonate at the moment, leading to disproportion of calcium and magnesium and the presence of sodium ions as the dominant ion in solution (Table 3). Chloride and boron were also found concentrated more in middle stream than up and downstream because of a dynamic significant encroachment activities occurring in the middle stream. Likewise, the presence of calcium, copper and zinc emphasizes the dynamic of heavy metal (Copper and zinc) of leaching by underground water in the upstream section whilst calcium may have originated from sedimentary rock weathering and changes when constructing dam upstream. Such rocks may be calcite, aragonite, gypsum and anhydride. Downstream of the scheme, there was high concentration of nitrate, sulphate and potassium ions due to heavy agricultural activity going on and other encroachments. Therefore, it is noted that the flow of fertilizers (Urea and NPK) actually used by rice farmer's cooperative in farming activities which lead to Nitrate, potassium and sulphate is being deposited in downstream.

According to Hayal and Seyoum [22], nitrate, potassium and sulphate ions are among the highly soluble chemicals and may quickly reach water bodies from soil, organic matter, manures, and artificial fertilisers. On the other hand, Bauder *et al.* [21] stated that the sulphate ion is a major contributor to salinity in Colorado irrigation waters and sulphate in irrigation water has fertility benefits and may interfere with the uptake of other nutrients. However, the sulphate precipitates easily and settles to the bottom sediment of the river. According to Manyaneza *et al.* [23], sulphate silicate and phosphate are the hydro-chemical tracers which used to explain the impact of water quality with surface runoff and inform the processes that occur within the catchment, and to estimate the sediment deposit in the stream. The same scenarios were observed in the study area where the hillsides in downstream were shaped by human induced activity which accelerates the erosion and sediment deposit in downstream. The different streams and their replications in the variables tested showed the least significant difference in water quality as one moves from upstream to downstream (Table 4).

**Table 4: ANOVA table by Fisher's protected LSD at (P< 0.05)**

| **Source of variation** | DF | To | pH | $E_C$ | TDS | $NO^{-}_{3}$ | $SO^{--}_{4}$ | $CL^-$ | $B^-$ |
|---|---|---|---|---|---|---|---|---|---|
| Replication | 5 | 8.117*** | 0.19264** | 2063.3*** | 10383.2*** | 8.8038*** | 6.447$^{NS}$ | 363.11*** | 0.00476$^{NS}$ |
| Streams | 2 | 66.385*** | 0.19989* | 255.3$^{NS}$ | 218.7$^{NS}$ | 2.4848$^{NS}$ | 230.854*** | 129.03* | 0.07471** |
| Residual | 64 | 1.378 | 0.04257 | 206.4 | 109.6 | 0.9682 | 7.683 | 27.88 | 0.00171 |

***(*), (**), (***): Significance respectively at*** $\alpha$: 0.05, 0.01 *and* 0.001

$^{(N.S)}$: *No significant difference*

**(Continuous Table 4)**

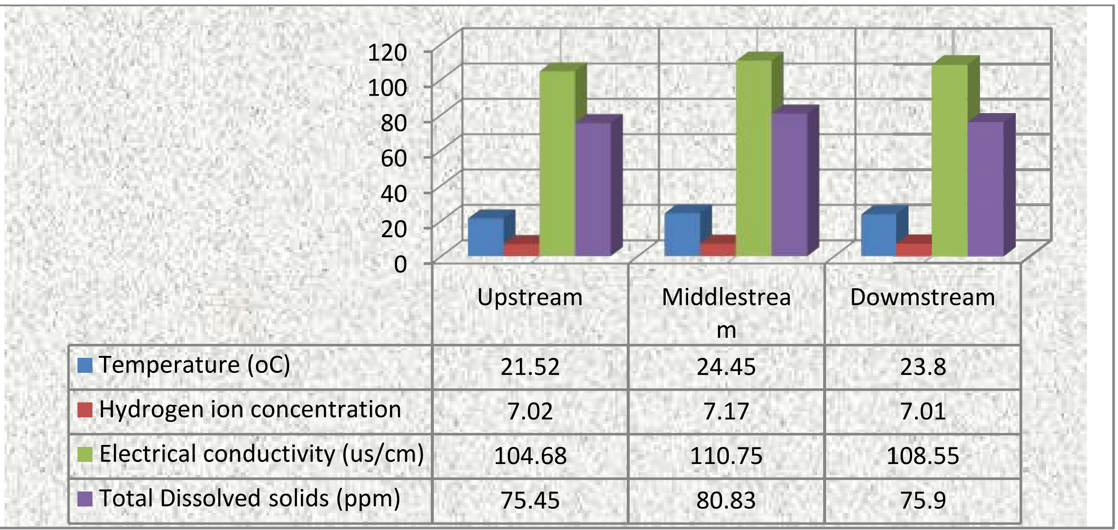
| Source of variation | DF | $Ca^{++}$ | $Mg^{++}$ | $K^+$ | Na+ | $Cu^{++}$ | $Zn^{++}$ |
|---|---|---|---|---|---|---|---|
| Replication | 5 | 36.3*** | 9.664*** | 276.04*** | 37.3623*** | 0.02199042*** | 0.00633297*** |
| Streams | 2 | 17.474* | 1.4261$^{NS}$ | 34.47$^{NS}$ | 23.2437*** | 0.00091102*** | 0.00000609$^{NS}$ |
| Residual | 64 | 3.733 | 0.4766 | 17.59 | 0.9676 | 0.00007784 | 0.00008216 |

*(*), (**), (***): Significance respectively at* $\alpha$: 0.05, 0.01 *and* 0.001

$^{(N.S)}$: *No significant difference*

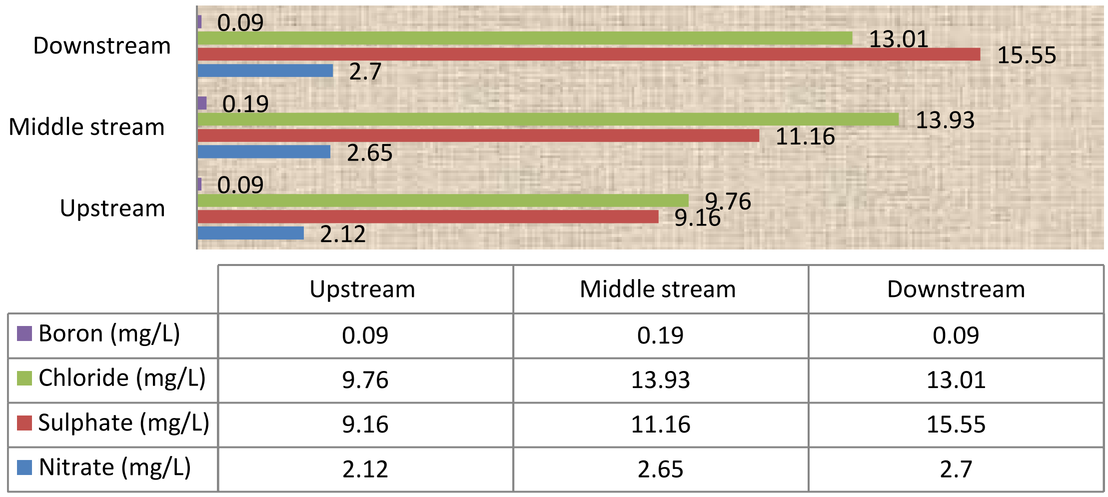
Using Gen Stat 12th Edition software, by multiple comparisons of general ANOVA table by Fisher's protected Least Significant Difference (LSD) at 0.05 probability [P($\alpha$)]. The summarized results were found almost the significant different (Table 4). These prove dynamic variation of stream sections (upstream, middle stream, downstream) in term of water quality because of different encroachments by human being in the study area.

To understand the distribution of physico-chemical parameters measured for irrigation water quality, we considered three important groups, such as the group of physical parameters, which were directly measured in the field: (Temperature (T°C), Electrical Conductivity (ECw), Total Dissolved Solids (TDS) and Hydrogen ion concentration (pH). The Group of anions ($NO_3^-$, $SO_4^{--}$, $Cl^-$, $B^-$,) and cations ($Ca^{++}$, $Mg^{++}$, $Na^+$, $K^+$, $Cu^{++}$ and $Zn^{++}$) were also considered in ensuring the meaningfulness of the graph plotted. Emongor et al. (2005) studied the irrigation water in Bostwana. The water contained varying amounts of cations and anions. Among them, the main soluble cations were $Ca^{++}$, $Mg^{++}$, $Na^+$ and $K^+$, and anions were $Cl^-$, $SO_4^{--}$, $CO_3^{--}$ and $HCO_3^-$. Out of the soluble constituents, $Ca^{++}$, $Mg^{++}$, $Na^{++}$, $Cl^-$, $SO_4^{--}$, $HCO^-_3$ and $B^-$ are of prime importance in judging the water quality for irrigation. Therefore, the results of irrigation water quality from the study area were grouped and plotted, looking on three consecutive groups as physical parameters, anions and cations (Figure1; Figure2 and Figure 3) consecutively.



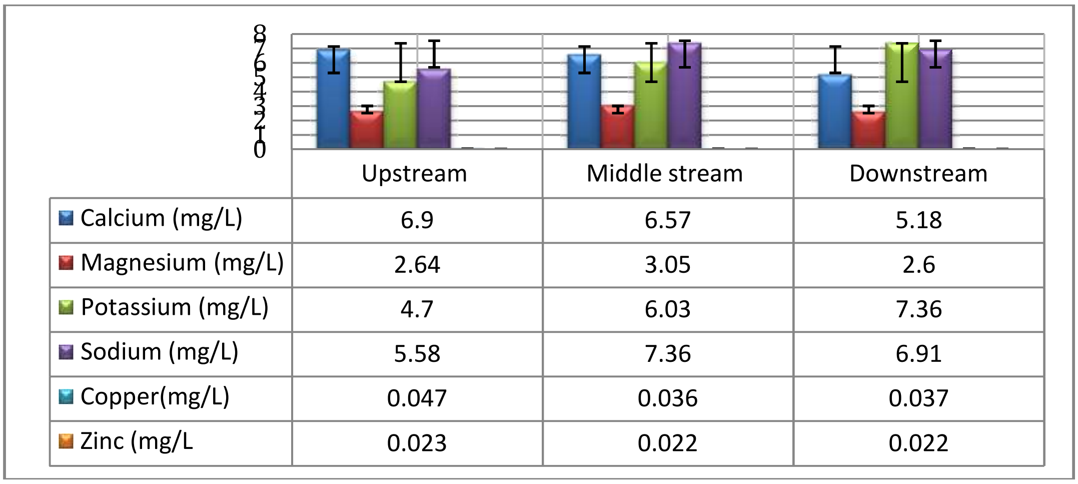
| | Upstream | Middlestream | Dowmstream |
|---|---|---|---|
| 🟦 Temperature (oC) | 21.52 | 24.45 | 23.8 |
| 🟥 Hydrogen ion concentration | 7.02 | 7.17 | 7.01 |
| 🟩 Electrical conductivity (us/cm) | 104.68 | 110.75 | 108.55 |
| 🟪 Total Dissolved solids (ppm) | 75.45 | 80.83 | 75.9 |

Figure1: Streams distribution of the physical water parameters measured in Rusurirwamujyinga rice irrigation scheme.



| | Upstream | Middle stream | Downstream |
|---|---|---|---|
| 🟪 Boron (mg/L) | 0.09 | 0.19 | 0.09 |
| 🟩 Chloride (mg/L) | 9.76 | 13.93 | 13.01 |
| 🟥 Sulphate (mg/L) | 9.16 | 11.16 | 15.55 |
| 🟦 Nitrate (mg/L) | 2.12 | 2.65 | 2.7 |

**Figure 2:** Streams distribution of the anions in Rusurirwamujyinga rice irrigation scheme



| | Upstream | Middle stream | Downstream |
|---|---|---|---|
| 🟦 Calcium (mg/L) | 6.9 | 6.57 | 5.18 |
| 🟥 Magnesium (mg/L) | 2.64 | 3.05 | 2.6 |
| 🟩 Potassium (mg/L) | 4.7 | 6.03 | 7.36 |
| 🟪 Sodium (mg/L) | 5.58 | 7.36 | 6.91 |
| 🟦 Copper(mg/L) | 0.047 | 0.036 | 0.037 |
| 🟧 Zinc (mg/L | 0.023 | 0.022 | 0.022 |

**Figure 3**: Streams distribution of the cations in Rusurirwamujyinga rice irrigation scheme

## CONCLUSIONS

The study on spatial variability of water quality and its response on growth of irrigated rice in Rusurirwamujyinga sub-catchment showed that it was suitable for irrigation. Significant differences were observed for all variables assessed. There is a significant difference in water quality among stream positions (upstream, middle and downstream). Due to the pressure of human encroachment surrounding the irrigation scheme, from upstream to downstream, several pollutants, sediment loss, dam siltation along the river and canals were observed as signals of resource degradation in the catchment. The unequal distribution of irrigation water from upstream to downstream was also assessed as the main cause of decreasing production, dryness in middle and downstream section, especially in the dry season and this cause some conflicts among farmers.

If interventions are not effected to control and monitor water quality and quantity in the irrigation scheme, pollution and siltation will render the water unsuitable in future. The middle stream and the downstream will continue to suffer from water quality risk and water shortages because of over encroachment. These conclusions were justified by the significant change of water quality observed in different stream positions.

## REFERENCES

1. Emamgholizadeh, S. (2008). Water Quality Assessment of the Kopal River (IRAN). International Meeting on Soil Fertility Land Management and Agroclimatology. Turkey, 2008. p: 827-837
2. Stoner, J.D., D.L. Lorenz, R.M. Goldstein, M.E. Brigham, and T.K. Cowdery. (1998). Water Quality in the Red River of the North Basin, Minnesota, North Dakota, and South Dakota. 1992-95: USA. Geological Survey Circular 1169. *On line at <URL: http:/.water. usgs.gov/pubs/circ1169>* pdf. Accessed on 17th October.2012.
3. Antonopoulos, V.Z., Papamichail, D.M., Mitsiou, K.A. (2001). Statistical and trend analysis of water quality and quantity data for the Strymon River in Greece, Journal of hydrology and earth system Sciences 5: 679–691.
4. Larsen, S.E., Kronvang, B., Windolf, J., Svendsen, L.M. (1999). Trends in diffuse nutrient concentrations and loading in Denmark: Statistical trend analyses of stream monitoring data. Journal of Water Science Technology 39 (12), 197–205.
5. Huang, W. and Foo, S. (2002). Neural network modelling of salinity variation in Apalachicola River. Water Research 36, pp356–362.
6. Holden, P. and Thobani, M. (1996). Tradable water rights: A property-rights approach to resolving water shortages and promoting investment. In *Strategies for intersectoral water management in developing countries: Challenges and consequences for agriculture,* eds. Richter. 284pp.
7. Food and Agriculture Organization (2003). AQUASTAT Information System on Water and Agriculture Country Profiles report: http:// www.fao. Org/country profile/ default.asp? search= search iso3=Rwa. Accessed 3rd November 2012.
8. Longenecker, D.E and Lyerly, P.J. (Ed) (1994). Control of Soluble Salts in Farming and Gardening. Texas Agricultural Experiment Station, Texas A and M University System College Station. http://www.lubbock. tamu.edu / irrigate/documents/2074410-B1667 pdf. Accessed on 07th 10.2012.
9. Rhoades, J.D. (1993). Reducing salinization of soil and water by improving irrigation anddrainage management: Prevention of Water Pollution by Agriculture and Related Activities.Proceedings of the FAO Expert Consultation, Santiago, Chile, 20-23 Oct. 1992.Water Report 1 FAO, Rome. 122 pp.
10. Ministry of Agriculture and Animal resources. (2001). "National Rice Programme Report"40pp.
11. Jagwe, J.N., Okoboi, G. and Hakizimana P. (2003). Marketing Survey of the Rice sub-sector in Rwanda ATDT- CIAT / ISAR / FOODNET. A draft Report. 53pp

12. Phil, T., Earl V., Charles, W. and Nathan, S. (2000). Soil and water management for rice Irrigation and water quality. http://wwwArgriculture. Org/soil water/irrigation/rice/quality.pdf. Accessed on 17 October 2011.
13. Yutaka, M. (2008). Monitoring and management of irrigation water quality in Japan. Department of Environmental Management, School of Agriculture, Kinki University Japan: http:/www.agnet.org/library/ac /2008c/ac/2008c pdf. Accessed on 05th November, 2012.
14. Hoffman, G.J., Rawlins, S.L., Oster, J.O., Jobe, J.A. and Merril, S.P. (1983). Leaching requirements of salinity control. Wheat, Sorghum and Lettuce. *Journal of Agricultural Water Management 2: 177-192*
15. Guy F. (1995) Irrigation water quality standard and salinity management strategy. The Texas A and M University press 15 pp.
16. Harvand, M.A. (1999). Interpreting turfgrass irrigation water test result. university of California, Division of Agriculture and Natural resources htt://anrcatalog.ucdavis.ed publication 8009.
17. Islam, M. S. and Shamsad, S. Z. K. M. (2009). Assessment of irrigation water quality of Bogra District in Bangladesh Bangladesh Journal of . Agriculture Research 34(4) : 597-608,
18. Niyotwambaza, H.C. (2009). Nutrient distribution in a fish pond at rwasave fish farming and reseach station. Msc. thesis in Water Resources and Environmental Management National University of Rwanda, Department of Civil Engineering, Butare Rwanda. 55pp.
19. Obiefuna, G.I. and Sheriff, A. (2011). Assessment of Shallow Ground Water Quality of Pindiga Gombe Area, Yola Area, NE, Nigeria for Irrigation and Domestic Purposes. Research Journal of Environmental and Earth Sciences 3(2): 131-141.
20. Kumar, N.R, Rajal, S. and Nirmal, K.J. (2011). Assessment of seasonal variation and water quality index of Sabarmati river and Kharicut Canal at Ahmadabad, Gujarat, Indian Electronically Journal of Agriculture and Food Chemistry 10: pp 2248-2261
21. Bauder, T.A., Waskom R.M. and. Davis, J.G. (2003). Irrigation water quality criteria. Colorado State University Cooperative Extension. http://www.ext.colostate.edu/pubs/crops/00506.html Accessed on 2nd November, 2012)
22. Hayal, D.Y. and Seyoum, M. (2009). Water quality parameters and macroinvertebrates index of biotic integrity of the Jimma wetlands, Southwestern Ethiopia Journal of Wetlands Ecology, Vol. 3, pp 77-93
23. Munyaneza, O., Uzayisenga, C., Nkurunziza, T., Bizimana, R. and Ndayisaba C. (2010). Identification and quantification of runoff generation processes during flood and drought in Migina catchment Southern of Rwanda. NBICBN- Rwanda node Report 45p.
24. American Public Health Association (2005). Standard Methods for the Examination of Water and Wastewater. 21st edition, Centennial Edition, Washington D C, USA 399p
25. Bartram, J. and Ballance, R. (Ed) (1996). "A practical guide to the design and implementation of freshwater studies and monitoring programmes" 308 pp

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