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STUDY OF HEAVY METALS VARIABILITY AND THEIR EFFECT ON PLANT GROWTH IN KANZENZE RIVER OF UPPER AKAGERA CATCHMENT, RWANDA

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ABSTRACT

Agricultural swamps are among the major fruitful and exposed to heavy metals deposition and contributes to ecological concerns. Heavy metals are mainly pollutants to deteriorate water quality and affect plant health through leaching and seepage process from industrial services, anthropogenic activities, erosion and mining activities. The study aimed to assess heavy metals, water quality and their effect on plant growth along Kanzenze Swamp of the Akagera Upper Catchment. The total of Sixteen chemical parameters of water including Calcium, Magnesium, Sodium, Potassium, Copper, Zinc, Manganese, Lead, Cadmium, Chromium, pH, Electrical Conductivity, Sodium Adsorption Ratio, Magnesium hazards, Kelly Index and Soluble Sodium Percent were analyzed and observed values were thereafter compared with international standards values recommended by Food and Agriculture Organization. Photometric methods and Atomic Adsorption Spectrometer machines were used to detect the heavy metals while analytical. Descriptive analysis and Principal Components Analysis techniques were used to correlate water quality parameters for similarities and dissimilarities through cluster analysis. All statistical analysis were performed by using Statistical Package for Social Science version 22.0. The study findings shows that most water use for irrigation is polluted by heavy metals with maximum values compared to Rwanda national and international permissible standards for irrigation. The heavy metals with highest content included Calcium, Magnesium, Potassium, Copper, Manganese, Cadmium and Chromium. Hence farmers relaying on this water may be disposed to health hazards issues and other environmental concerns. Therefore some effective measures like water treatments are compulsory vital needed to boost the quality of water for irrigation purpose.

Contribution/Originality: This study is one of very few studies which have investigated heavy metals variability and their effect on plant growth in Kanzenze river of Upper Akagera Catchment, Rwanda for water quality improvement in irrigation purposes.

1. INTRODUCTION

Heavy metals are mainly pollutants to deteriorate the water quality for irrigation after the environmental concentration. Heavy metals can enter in water bodies through the leaching and seepage process sourced by industrial services, anthropogenic activities, erosion and mining activities and discharging heavy metals into streams, lakes, rivers, and groundwater. The worldwide concern of heavy metals sedimentation and transport affects ground water, river flow and water bodies in general. The view of worldwide farmers proved that most vulnerable farmers become extra worry over the potential growth of heavy metals in various ecosystems including the agricultural land [1]. The most research findings focused that main heavy metals are sourced from natural weathering and human activities and these increase its storage in water bodies [2]. The scholars' findings revealed that for instance the copper's availability is low as 1000 mg/ litre to 2000mg/litre L and was concluded that it has an antagonistic effects on marine organism [3]. The high level content of Copper in Water body might disturb the human being's multiplication, physiological growth and behavioral change on a variety of marine organisms. Moreover, high intakes of copper have been associated with liver failure and gastrointestinal problems in humans [4]. Accumulation of heavy metals in soil complex is sourced from watered with high pollutions. Low agricultural productivity of horticultural crops farmed in Kanzenze swamp, yellowish and deficiency of soil nutrients is associated to heavy metals present in Irrigation water from Kanzenze River used by most farmers in dry season. Scholars in Rwanda like [5] have proved that the well of Gahanga sector had a very extraordinary cadmium content which is possibly linked to pollution from the landfill place located in its neighborhood whereby eighteen percent of the total samples contained maximum limits bouncing the WHO standards and its drainage outlets affect the water body of Kanzenze river located in Ntarama sector of Bugesera district. Currently, there is no specific study that has been undertaken to evaluate levels of on heavy metals in Kanzenze River which will affect soil of the swamp. Hence, there is a need to support the local farmers by the way of taking up research so as to solve the field problem that led to increased crop production and improved economic welfare of the farmers around the Akagera Upper Catchment. This caused the researcher to take the study of assessing the levels of heavy metals present in water from Kanzenze River for sustainable irrigation in Rwanda as well as to carry out the feasible way to solve the problem to improve water quality for irrigation and lead to improving the crop production.

1.1. Study Areas Description

This subject was undertaken on behalf of conducting a feasibility study in Kanzenze Swamp of Akagera Upper Catchment. Kanzenze Swamp is located in Bugesera District, Ntarama sector where it is drained to Akanyaru River at Rurambi marshland geographically located at coordinates of -2.0613 and 30.0877 respectively. According to District Agricultural Report, 2003 Kanzenze marshland comprised with four main areas including Muzi, Karugenge, Nyamabuye and Karumuna sites. The total area of the swamp is about 501 ha in which 300 ha are arable areas. The major crops grown in the swamp are tomatoes, carrots, onions, eggplants and chilly. Map of Kanzenze swamp is shown in Figure 1 with four sites using Arc GIS 10.5 respectively.

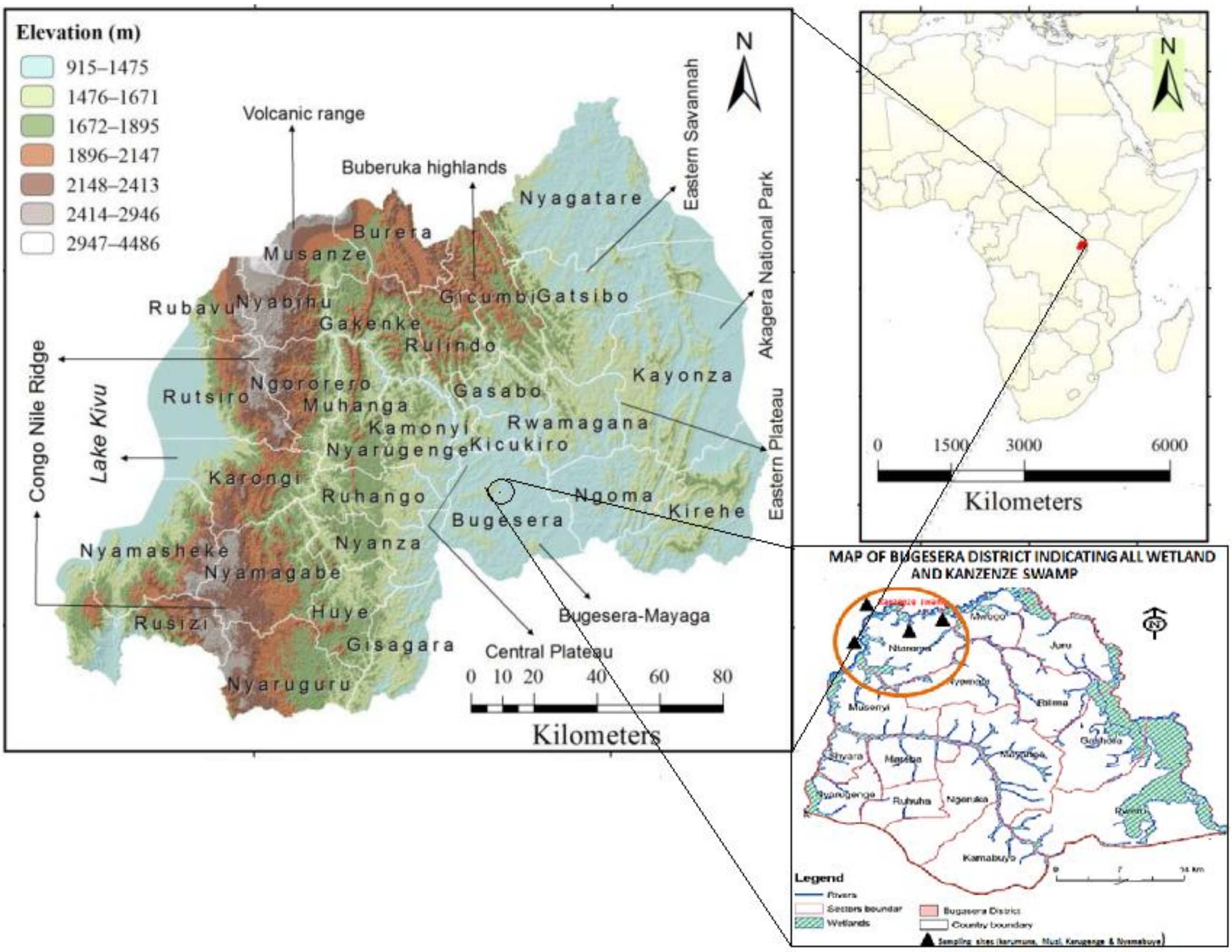

Figure-1. Kanzenze swamp showing study area sites.

Source: NISR-CGIS-NUR, 2008.
CGIS: Collected Geographic Information System.
NUR: National University of Rwanda.
NISR: National Institute of Statistics of Rwanda.

2. MATERIAL AND METHODS

2.1. Materials

The various materials used to carry out the study of heavy metals variability and its effect on plant growth in Kanzenze River presented and discussed here. The analysis of chemical properties of water were carried out in the Rwanda Standard Board laboratory. The following list of materials was referred to and used. The materials used included A.A.S Machine, PH meter (PH Probe), TDS Probe, Nitric acid for titration process, Refrigerators to cool down water samples, GPS Etrex 10 for geographical coordinates, Digestion flask 100 mL, graduated cylinders for water volume measurement, Bid stilled water, Pyrex beaker, Erlenmeyer flask, Graduated pipettes and needful Chemical reagents.

2.2. Methods

The collected water from the Kanzenze River of Upper Akagera catchment in the 4 sites comprising surface water samples were tested for different various chemical parameters as per the standard methods analysis protocols APHA[9] .The total of 12 samples collected in Kanzenze river at surface water level (Surface water only). Based on study's schedule, the collection of surface in short sunny season of January to End of March was considered as period of study (January to March/ 2020). Samples of Kanzenze River of the Upper Akagera catchment were grabbed in sterilized sampling polyethylene bottles of 250 ml capacity which is rinsed three times with samples before storing water, collected samples were preserved and instantaneously transported to laboratory and store at 4^0C until their diverse chemical parameters were analyzed. The comparison of the heavy metals present in Kanzenze River was made regarding the standards (permissible limits) for irrigation purposes.

2.2.1. Water Sampling Procedures

For Water sampling procedures to collect samples from surface water were identified and followed. First the 12 samples were taken from surface water as primarily are used by farmers to irrigate the crops in Kanzenze swamp during the short sunny season. The total of 12 water samples were collected from all four sites Muzi, Karugenge, Nyamabuye and Karumuna sites and thereafter transported in plastic bottles for laboratory analysis. The samples collected were kept in containers that were thoroughly washed to avoid any contamination.

2.2. 2. Water Sample Digestion to Detect Heavy Metals in Water

One litre of the water collected from the Kanzenze River in the river was first pickled with 1.5 ml of rigorous HNO_3. In addition, 50ml of the solution was relocated to an evaporating system and removed 20 ml. Then 10ml containing 8 moles of Nitric acid (HNO_3) concentrated at 98% purity was added to catalyse the reaction and evaporation rate. It was then refrigerated and de-ionized with distilled water of 50 millilitres added and then the final solution was filtered. The process was repeated for whole needed heavy metals detection. The filtrate was quantitatively transferred to a 100 ml volumetric flask with two portions of 5 ml of de-ionized distilled water. The solution was diluted to mark and mixed thoroughly by shaking. The heavy metals under study were thereafter determined using Atomic Absorption Spectrophotometer (AAS) machine as prescribed in the research conducted by [6].

2.3. Data Analysis

The measured data will be kept in a Microsoft Excel file and later using either SPSS 22.0 and STATA 13.0. The overall significance of soil samples by sites will be evaluated at the 5% level of probability ($p \leq 0.05$). Descriptive statistics like means, median, variance, standards deviation, minimum, maximum and coefficient of variation were used to interpret data. The correlation analysis of chemical parameters of water were performed and discussed through Application of Principal Components Analysis (PCA) to indicate the interrelationship between components during the water quality assessment. It is based on Eigenvalue analysis of the covariance or correlation matrix. Principal component analysis (PCA) was performed to connect different studied factors by cluster analysis (CA) to estimate resemblances and divergences between sampled variables. According to classification made by Shrestha and Kazama [7] Eigenvalues of 1.0 or greater are considered significant classification of factor loading in thus "strong when r>0.75", "moderate when r is between 0.75-0.50" and "weak when r is between 0.50-0.30 respectively [8].

3. RESULTS AND DISCUSSION

3.1. Determination of Heavy Metals Present in Irrigation Water

The main drive of this objective is to determine levels of heavy metals present in Kanzenze water body. The heavy metals determined in the irrigation water are Ca, Mg, Na, K, Cu, Zn, Mn, Pb, Cd and Cr which are important parameters during the heavy metals assessment.

3.1.1. Concentration of Heavy Metals Present in Kanzenze River Water

The water samples taken from Kanzenze River were transferred to Rwanda Standard Board Laboratory for water quality assessment. The heavy metals detected were Ca, Mg, Na, K, Cu, Zn, Mn, Pb, Cd and Cr. The mean concentration of each heavy metal was presented and interpreted by their averages. The discussion of heavy metals was done by type of available and detected heavy metals and their concentration were expressed in ppm (parts per millions) per sampling site as indicated in Table 1.

Table-1. Concentration of heavy metals in Kanzenze river water.

Water samples		Mean of the heavy metals concentration of water samples in ppm									
		Ca	Mg	Na	K	Cu	Zn	Mn	Pb	Cd	Cr
1		14.580	24.784	4.649	34.185	0.850	0.948	257.614	1.120	0.370	4.236
2		36.190	32.420	6.256	29.842	0.684	0.894	159.897	0.886	0.784	1.752
3		5.590	22.652	1.287	8.892	0.799	0.987	221.984	0.984	0.199	1.008
4		21.650	22.751	11.761	15.119	0.867	0.868	97.829	1.668	0.781	2.930
5		12.422	27.833	5.415	11.677	0.925	0.898	127.929	0.987	0.782	3.942
6		30.398	24.944	3.370	22.343	0.136	0.887	89.664	0.947	0.977	2.847
7		29.445	23.741	11.558	12.871	0.282	0.748	278.784	0.849	0.883	4.226
8		30.920	18.980	8.644	10.242	0.979	0.898	118.250	0.889	0.769	2.996
9		20.220	19.150	12.117	21.131	0.964	0.888	94.750	0.878	0.687	2.271
10		15.620	15.280	8.265	31.393	0.996	0.653	121.621	1.854	0.876	2.996
11		27.230	18.420	5.583	16.300	0.889	0.937	196.750	1.681	0.971	4.586
12		26.020	25.120	12.940	17.490	0.586	0.749	113.340	1.853	0.845	4.628
Descriptive statistics of water samples analysed	Mean	22.524	23.006	7.654	19.290	0.746	0.863	156.534	1.216	0.744	3.202
	P50	23.835	23.246	7.261	16.895	0.859	0.891	124.775	0.986	0.783	2.996
	Var	82.471	21.440	14.590	73.739	0.078	0.009	4379.857	0.171	0.054	1.335
	SD	9.081	4.630	3.820	8.587	0.280	0.097	66.180	0.414	0.233	1.155
	Min	5.590	15.280	1.287	8.892	0.136	0.653	89.664	0.849	0.199	1.008
	Max	36.190	32.420	12.940	34.185	0.996	0.987	278.784	1.854	0.977	4.628
	Range	30.600	17.140	11.653	25.293	0.861	0.335	189.120	1.005	0.778	3.620
	CV	0.403	0.201	0.499	0.445	0.375	0.112	0.423	0.340	0.314	0.361
	N	12	12	12	12	12	12	12	12	12	12

3.1.1.1. Calcium in Irrigation Water

Table 1 shows the fact that 12 water samples were analysed. The average heavy metal calcium content in the irrigation water was found to be 22.524 ppm. The range varies from 5.590 ppm to 36.190 ppm. The standard deviation was found to be 9.081 with the coefficient of variation of 0.403 which is less than to 0.5. It shows that there is less appreciable effect of calcium in water for irrigation. The natural sources of calcium is from basically all solids and rocks and limestone application during soil reclamation. Rwanda Standard Board has fixed the permissible limits of potassium contend and other heavy metals in water for irrigation in RS 188 and RS 106: 2016. However, as per FAO guidelines for irrigation, calcium content should be in range of 0-20 ppm [9] but the estimation of calcium content in the irrigation water of Kanzenze river was found to be 22.524 ppm, which is slightly higher but statistically insignificant compared to FAO guidelines. Hence, calcium content in the river water is under permissible range for irrigation.

3.1.1.2. Magnesium Content in Irrigation Water

Table 1 shows the fact that 12 water samples were analysed from the laboratory of Rwandan Standard Board. The average heavy metal magnesium content in the irrigation water was found to be 23.006ppm. The range varies from 15.28 ppm to 32.42 ppm. The standard deviation was found to be 4.630 ppm with the coefficient of variation of 0.201 which is less than 0.5 respectively. In Kanzenze River, the high concentration of Magnesium is associated to natural presence in water body mainly the Akagera Upper Catchment that drains out the discharge to Kanzenze River. Rwanda Standard Board has fixed the permissible limits of potassium contend and other heavy metals in water for irrigation in RS 188 and RS 106: 2016. However, as per FAO guidelines for irrigation, magnesium content should be in range of 0-5 ppm [9] but the estimation of magnesium content in the irrigation water of

Kanzenze river was found to be 23.006 ppm, which very high compared to FAO guidelines and hence, there is a need to take care of water treatment for irrigation purposes.

3.1.1.3. Sodium Content in Irrigation Water

Table 1 shows the fact that 12 water samples were analysed. The average heavy metal sodium content in the irrigation water was found to be 7.654 ppm. The range varies from 1.287 ppm to 12.940 ppm. The standard deviation was found to be 3.82 with the coefficient of variation of 0.499 which is almost equal to 0.5. It shows that there is appreciable effect of sodium in water for irrigation. In Kanzenze River, the high concentration of Magnesium is associated to natural presence in water body mainly the Akagera Upper Catchment that drains out the discharge to Kanzenze River. Rwanda Standard Board has fixed the permissible limits of potassium contend and other heavy metals in water for irrigation in RS 188 and RS 106: 2016. However, as per FAO guidelines for irrigation, magnesium content should be in range of 0-5 ppm [9, 10] but the estimation of sodium content in the irrigation water of Kanzenze river was found to be 7.654 ppm, which is within the prescribed range given by FAO guidelines. Hence, sodium content in the river water is under permissible range for irrigation.

3.1.1.4. Potassium Content in Irrigation Water

Table 1 shows the fact that 12 water samples were analysed from the laboratory of Rwandan Standard Board. The average heavy metal potassium content in the irrigation water was found to be 19.290 ppm. The range varies from 8.892 ppm to 34.185 ppm. The standard deviation was found to be 8.587 ppm with the coefficient of variation of 0.445 which is less than 0.5 respectively. The source of strong concentration of potassium in the swamp land is mainly due to fertigation of soil with water polluted with potassium chloride in which via leaching process at high depths of irrigation. But nationally, Rwanda Standard Board has fixed the permissible limits of potassium contend and other heavy metals in water for irrigation in RS 188 and RS 106: 2016. However, as per FAO guidelines for irrigation, potassium content should be in range of 0-2 ppm as adopted by [9], but the estimation of potassium content in the irrigation water of Kanzenze river was found to be 19.290 ppm, which is very high compared to FAO guidelines. There is a need to take care of water treatment for irrigation purposes.

3.1.1.5. Copper Content in Irrigation Water

Table 1 shows the fact that 12 water samples were analysed from the laboratory of Rwandan Standard Board to detect trace elements. The average copper content in the irrigation water was found to be 0.746 ppm. The range varies from 0.136 ppm to 0.996 ppm. The standard deviation was found to be 0.280 ppm with the coefficient of variation of 0.375 which is less than 0.5 respectively. Rwanda Standard Board in RS 188 and RS 106: 2016 and Food and Agriculture Organization have fixed the permissible limits of copper contend and other heavy metals in water for irrigation. As per FAO guidelines, for irrigation, recommended maximum copper content should not exceed 0.2 ppm [9] but the estimation of copper content in the irrigation water of Kanzenze River was found to be 0.746 ppm, which is very high compared to FAO guidelines. As prescribed in the FAO remarks, there is an effect of toxic to some of plants when the copper content is between 0.1 to 1.0 mg/l in nutrient solutions. Thus, there is a need to take care of water treatment for irrigation use.

3.1.1.6. Zinc Content in Irrigation Water

Table 1 shows the fact that 12 water samples were analysed from the laboratory of Rwandan Standard Board to detect trace elements. The average zinc content in the irrigation water was found to be 0.863 ppm. The range varies from 0.653 ppm to 0.987 ppm. The standard deviation was found to be 0.097 ppm with the coefficient of variation of 0.112 which is less than 0.5 respectively. Rwanda Standard Board in RS 188 and RS 106: 2016 and Food and Agriculture Organization have fixed the permissible limits of zinc contend and other heavy metals in water for irrigation. As per FAO guidelines, for irrigation, recommended maximum zinc content should not exceed 2.0 ppm [9] but the estimation of zinc content in the irrigation water of Kanzenze River was found to be 0.863 ppm, which is very high compared to FAO guidelines. As prescribed in the FAO remarks, there is an effect of poisonous to many plants at broadly unpredictable concentrations of zinc; but the harmfulness can be diminished by managing the pH > 6.0 in fine textured. Thus, there is a need to take care of water treatment for irrigation activities.

3.1.1.7. Manganese Content in Irrigation Water

Table 1 shows the fact that 12 water samples were analysed from the laboratory of Rwandan Standard Board to detect trace elements. The average manganese content in the irrigation water was found to be 156.534 ppm. The range varies from 89.664 ppm to 278.784 ppm. The standard deviation was found to be 66.180 ppm with the coefficient of variation of 0.423 which is less than 0.5 respectively. Rwanda Standard Board in RS 188 and RS 106: 2016 and Food and Agriculture Organization have fixed the permissible limits of Manganese contend and other heavy metals in water for irrigation. As per FAO guidelines, for irrigation, recommended maximum manganese content should not exceed 0.20 ppm [9] but the estimation of manganese content in the irrigation water of Kanzenze River was found to be 156.534 ppm, which is very high compared to FAO guidelines. As prescribed in the FAO remarks, there is an effect of toxic to a number of crops when the manganese content is above the prescribed limit of 0.20 ppm. Thus, there is a need to take care of water treatment for irrigation purposes.

3.1.1.8. Lead Content in Irrigation Water

Table 1 shows the fact that 12 water samples were analysed from the laboratory of Rwandan Standard Board to detect trace elements. The average lead content in the irrigation water was found to be 1.216 ppm. The range varies from 0.849 ppm to 1.854 ppm. The standard deviation was found to be 0.414 ppm with the coefficient of variation of 0.340 which is less than 0.5 respectively. Rwanda Standard Board in RS 188 and RS 106: 2016 and Food and Agriculture Organization have fixed the permissible limits of Lead contend and other heavy metals in water for irrigation. As per FAO guidelines, for irrigation, recommended maximum lead content should not exceed 5.0 ppm [9] but the estimation of lead content in the irrigation water of Kanzenze river was found to be 1.216 ppm, which is very low compared to FAO guidelines and hence there is no harmful effect to plants due to lead content.

3.1.1.9. Cadmium Content in Irrigation Water

Table 1 shows the fact that 12 water samples were analysed from the laboratory of Rwandan Standard Board to detect trace elements. The average cadmium content in the irrigation water was found to be 0.744 ppm. The range varies from 0.199 ppm to 0.977 ppm. The standard deviation was found to be 0.233 ppm with the coefficient of variation of 0.314 which is less than 0.5 respectively. Rwanda Standard Board in RS 188 and RS 106: 2016 and Food and Agriculture Organization have fixed the permissible limits of Cadmium contend and other heavy metals in water for irrigation. As per FAO guidelines, for irrigation, recommended maximum cadmium content should not exceed 0.01 ppm [9] but the estimation of cadmium content in the irrigation water of Kanzenze river was found to be 0.744 ppm, which is very high compared to FAO guidelines. As prescribed in the FAO remarks, there is an effect of toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Thus, there is a need to take care of water treatment for irrigation practices.

3.1.1.10. Chromium Content in Irrigation Water

Table 1 shows the fact that 12 water samples were analysed from the laboratory of Rwandan Standard Board to detect trace elements. The average chromium content in the irrigation water was found to be 3.202 ppm. The range varies from 1.008 ppm to 4.628 ppm. The standard deviation was found to be 1.155 ppm with the coefficient of variation of 0.361 which is less than 0.5 respectively. Rwanda Standard Board in RS 188 and RS 106: 2016 and

Food and Agriculture Organization have fixed the permissible limits of Chromium contend and other heavy metals in water for irrigation As per FAO guidelines, for irrigation, recommended maximum chromium content should not exceed 0.1 ppm [9] but the estimation of chromium content in the irrigation water of Kanzenze river was found to be 3.202 ppm, which is very high compared to FAO guidelines. As prescribed in the FAO remarks, this is not commonly documented as a vital growth element. Thus, there is a need to take care of water treatment for irrigation activities. Based on FAO sequence of heavy metals in descending order, the research findings showed that Kanzenze river has heavy metals ordered as follow: Mn>Mg>Ca>K>Na>Cr>Pb>Zn>Cu>Cd respectively in descending order of concentration 156.534 ppm to 0.744 ppm for Manganese (Mn) to Cadmium (Cd).

3.2. Principal Component Analysis for Water Quality Assessment

Raw data of heavy metals and other water quality parameters were analysed with Principal Component Analysis in Table 2. The principal components are produced in a consecutively well-ordered routine with diminishing charities to the variance, i.e. the first principal component clarifies greatest of the deviations existing in the original data, and continual principal components account for lessening magnitudes of the variance. After rotation, each variable will be only connected to one of the loading factors and each factor to be discussed here will have high correlation and weak correlation for one component with only a small set of variables and this method is suitable for classification of groundwater quality and that is why it was adopted as a technical model for water quality evaluation. In this case, according to classification made by Shrestha and Kazama [7] Eigenvalues of 1.0 or greater are taken statistically significant of factor loading identified. If correlation coefficient 'r' < 0.50 then the correlation relationship between variable is weak and if r is between 0.50 to 0.75 then there was moderate relationship among variables else if r > 0.75 then there will be strong relationship among variables [8]. The results for Principal Component Analysis combining heavy metals and water quality parameters are shown in the Table 2.

Based on principles of PCA, the findings showed five components PC for Ca, PC for Mg, PC for Na, PC for K and PC for Cu accounted for the cumulative value of 0.839 in Table 3.2, which is 83.9% of the total variance of original data set after transformation into factor analysis with Eigenvalues greater than one were statistically significant correlated with other factors from the same clusters.

3.2.1. Calcium as Principal Component for Water Quality and Its Clusters

Table 2 shows the total proportional variation value for the PC for Ca with 0.305 (30.5%), it shows that 30.5% of the variations are due to the first factor Ca, which is having highest effect. The Eigen value of Ca from Table 2 was found to be 5.482. It is higher than 1 and hence, it has strong effect on other factors**.** The correlation coefficient 'r' of Principal Component Ca with more than 0.5 was considered to be highly statistically significant based its magnitude and not based on the ± sign and shown in Figure 2.

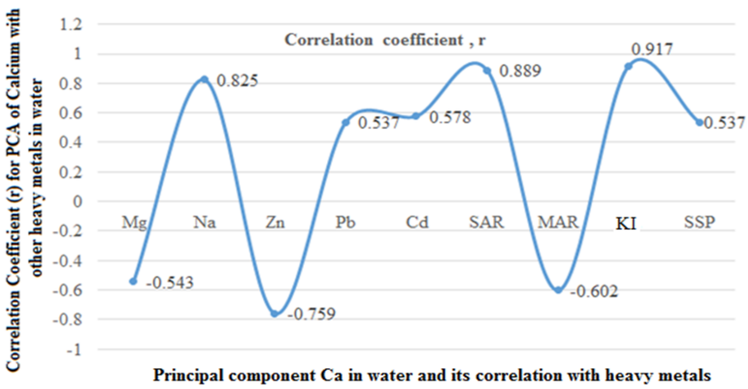

Figure-2. Variation of correlation coefficient of Calcium in water with its clusters.

Table-2. Principal component analysis for water quality (factor analysis).

Variables	Principal Components (PC) have meaningful interactions based on Eigen values > 1 and Correlation Coefficients are given in the table. Magnitude and (- sign) indicates inverse relationship of the factor									
	PC for Ca	**PC for Mg**	**PC for Na**	**PC for K**	**PC for Cu**	**PC for Zn**	**PC for Mn**	**PC for Pb**	**PC for Cd**	**PC for Cr**	**PC for pH**
Ca	0.234	0.773	-0.373	-0.049	-0.196	0.226	0.289	-0.123	0.123	-0.029	-0.053
Mg	-0.543	0.440	-0.234	0.235	0.337	0.394	-0.241	0.232	0.139	-0.045	0.020
Na	0.825	0.193	0.010	-0.149	0.456	0.200	0.100	-0.027	0.006	0.032	-0.021
K	0.143	0.019	0.021	0.952	-0.205	0.112	0.128	0.017	-0.030	0.002	-0.020
Cu	0.212	-0.702	0.188	-0.061	-0.084	0.074	0.326	0.471	0.280	-0.070	-0.005
Zn	-0.759	-0.193	-0.060	-0.221	-0.108	0.230	0.375	0.229	-0.202	0.183	0.059
Mn	-0.490	0.181	0.493	0.158	0.311	-0.372	0.314	-0.260	0.222	0.008	0.100
Pb	0.537	-0.109	0.583	0.025	-0.337	0.283	-0.315	-0.080	0.197	0.145	0.008
Cd	0.578	0.64	-0.173	-0.127	-0.364	-0.067	-0.168	0.137	0.026	0.016	0.160
Cr	0.289	0.543	0.692	-0.057	-0.013	-0.060	-0.008	0.248	-0.191	-0.195	0.020
pH	-0.428	-0.361	0.396	-0.081	-0.016	0.626	0.077	-0.320	-0.057	-0.124	0.066
EC	-0.347	0.678	0.636	-0.016	0.029	0.016	0.025	0.076	-0.006	0.075	-0.051
TDS	-0.347	0.678	0.636	-0.016	0.029	0.016	0.025	0.077	-0.006	0.075	-0.051
TH	-0.402	0.606	-0.51	0.358	0.260	0.077	-0.010	0.081	0.020	0.025	0.040
SAR	0.889	0.031	0.043	-0.100	0.415	0.126	0.079	0.004	-0.033	0.045	0.008
MAR	-0.602	-0.562	0.203	0.088	0.334	-0.056	-0.376	0.126	-0.001	0.026	0.010
KR	0.917	-0.131	0.066	-0.033	0.353	0.043	0.051	0.028	-0.054	0.054	0.033
SSP	0.537	-0.313	0.225	0.735	-0.017	-0.028	0.077	0.016	-0.122	0.030	0.024
Eigenvalue, difference, proportion and cumulative based on Factor analysis/correlation											
Eigenvalue	5.482	3.954	2.649	1.778	1.241	0.964	0.803	0.636	0.302	0.135	0.057
Difference	1.528	1.305	0.871	0.536	0.278	0.160	0.167	0.334	0.167	0.079	0.057
Proportion	0.305	0.220	0.147	0.099	0.069	0.054	0.045	0.035	0.017	0.008	0.003
Cumulative	0.305	0.524	0.671	0.770	0.839	0.893	0.937	0.973	0.989	0.997	1

Figure 2 reveals the fact that the positive value of correlation coefficient shows the direct proportional relationship between the principal components Ca with other heavy metals in irrigation water. The direct proportional relationship with Ca was found for the factors like Na, Pb, Cd, SAR, KI and SSP. It means these factors will increase as Ca increases in the irrigation water. The minus sign of the correlation coefficient shows the inverse relationship between the principal components Ca with other factors. The inverse relationship with Ca was found for the heavy metals like Mg, Zn and MAR. The values of r vary from -1 to 1. If the magnitude of the correlation coefficient r is > |±0.5|, it means there is high correlation between Ca and other variables considered. For example, KI has the highest coefficient of correlation of 0.917, it means for every 1 ppm addition of Ca with there is 91.7% increase in Kelly Index. The lowest coefficient of correlation of -0.759 is observed for Zn. It means for every addition of Ca there is 75.9% decrease of Zn content in irrigation water.

3.2.2. Magnesium as Principal Component for Water Quality and Its Clusters

Table 2 shows the total proportional variation value for the PC for Mg with 0.220 (22%), it shows that 22% of the variations are due to the first factor Mg, which is having highest effect after calcium. The Eigen value of Mg from table 3.2 was found to be 3.954. It is higher than 1 and hence, it has strong effect on other factors in the cluster**.** The correlation coefficient 'r' of Principal Component Mg with more than 0.5 was considered to be highly statistically significant based its magnitude and not based on the ± sign and shown in Figure 3.

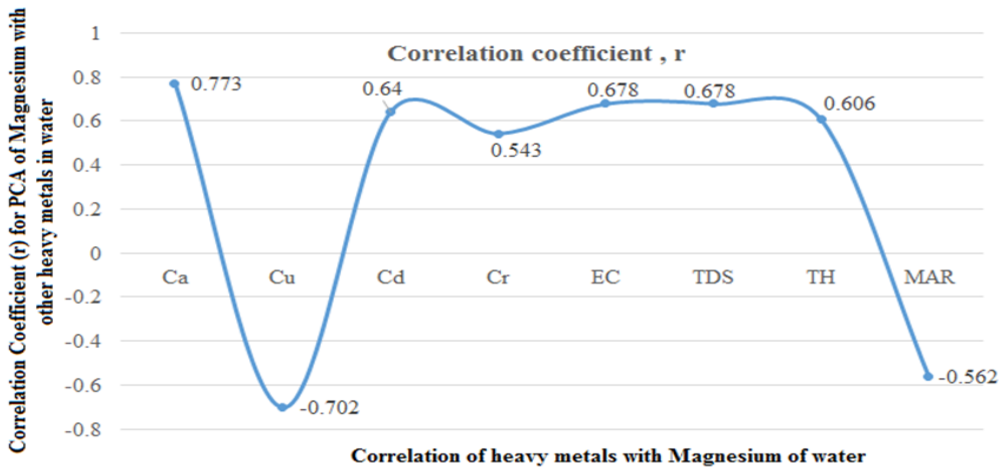

Figure-3. Variation of correlation coefficient of Magnesium in water with its clusters.

Figure 3 reveals the fact that the positive value of correlation coefficient shows the direct proportional relationship between the principal components Mg with other heavy metals in irrigation water. The direct proportional relationship with Mg was found for the factors like Ca, Cd, Cr, EC, TDS and TH. It means these factors will increase as Mg increases in the irrigation water. The minus sign of the correlation coefficient shows the inverse relationship between the principal components Mg with other factors. The inverse relationship with Mg was found for the heavy metals like Cu and MAR. The values of r vary from -1 to 1. If the magnitude of the correlation coefficient r is > |±0.5|, it means there is high correlation between Mg and other variables considered. For example, Ca has the highest coefficient of correlation of 0.773, it means for every 1 ppm addition of Mg with there is 77.3% increase in Ca in the water. The lowest coefficient of correlation of -0.702 is observed for Cu. It means that for every addition of 1mg/L of Mg there is 70.2% decrease of Cu content in irrigation water.

3.2.3. Sodium as Principal Component for Water Quality and its Clusters

Table 2 shows the total proportional variation value for the PC for Na with 0.147 (14.7%), it shows that 14.7% of the variations are due to the first factor Na, which is having highest effect after Ca and Mg. The Eigen value of Na from table 3.2 was found to be 2.649. It is higher than 1 and hence, it has strong effect on other factors in the cluster. The correlation coefficient 'r' of Principal Component Na with more than 0.5 was considered to be highly statistically significant based its magnitude and not based on the ± sign and shown in Figure 4.

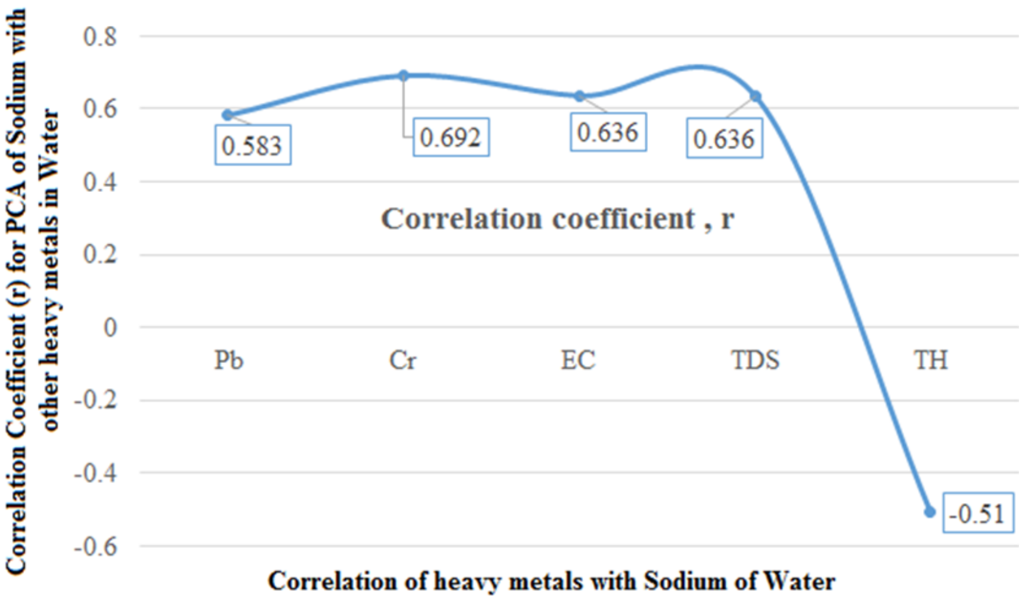

Figure-4. Variation of correlation coefficient of Sodium in water with its clusters.

Figure 4 reveals the fact that the positive value of correlation coefficient shows the direct proportional relationship between the principal components Na with other heavy metals in irrigation water. The direct proportional relationship with Na was found for the factors like Pb, Cr, EC and TDS. It means these factors will increase as Na increases in the irrigation water.

The minus sign of the correlation coefficient shows the inverse relationship between the principal components Na with other factors. The inverse relationship with Na was found for the Total Hardness (TH) of water. The values of r vary from -1 to 1. If the magnitude of the correlation coefficient r is > |±0.5|, it means there is high correlation between Na and other variables considered. For instance, Cr has the highest coefficient of correlation of 0.692, it means for every 1 ppm addition of Na, there is 69.2% increase in Cr in the water. The lowest coefficient of correlation of -0.51 is observed for Total hardness (TH). It means that for every addition of 1mg/L of Na there is 51% decrease of TH content of irrigation water.

3.2.4. Potassium as Principal Component for Water Quality and its Clusters

Table 2 shows the total proportional variation value for the PC for K with 0.099 (9.9%), it shows that 9.9% of the variations are due to the first factor K, which is having highest effect after Ca, Mg and Na. The Eigen value of Na from table 4.11 was found to be 1.778. It is higher than 1 and hence, it has strong effect on other factors in the cluster. The correlation coefficient 'r' of Principal Component K with more than 0.5 was considered to be highly statistically significant based its magnitude and not based on the ± sign and shown in Figure 5.

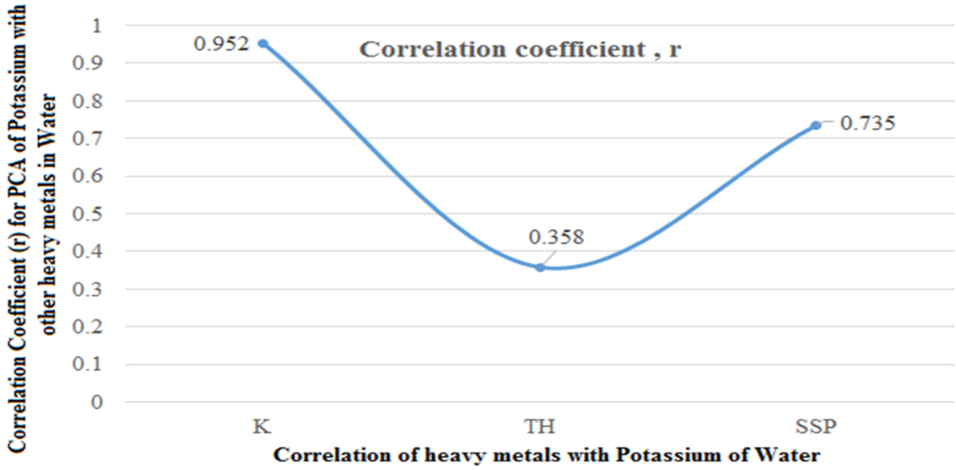

Figure-5. Variation of correlation coefficient of Potassium in water with its clusters.

Figure 5 reveals the fact that the positive value of correlation coefficient shows the direct proportional relationship between the principal components K with other heavy metals in irrigation water. The direct proportional relationship with K was found for the factors like K itself and other factors like TH and SSP. It means these factors will increase as K increases in the irrigation water. If the magnitude of the correlation coefficient r is > 0.5, it means there is high correlation between K and other variables considered. For instance, K has the highest coefficient of correlation of 0.952, it means for every 1 ppm addition of K in ions form in water for irrigation, there is 95.2% increase in K soluble content in the water. The second highest factor is SSP with correlation coefficient of 0.735. It means that the additional of 1ppm of K in the water, the soluble Sodium percent will be increased by 73.5% in the irrigation water. The highly correlation coefficient of K and SSP is to indicate that the K ions is the major constituent of Soluble Sodium Percent and once reduced or increased in water, it will deteriorate the quality of drinking and irrigation water use.

3.2.5. Copper as Principal Component for Water Quality and its Clusters

Table 2 shows the total proportional variation value for the PC for Cu with 0.069 (6.9%), it shows that 6.9% of the variations are due to the first factor Cu, which is having highest effect after Ca, Mg, Na and K. The Eigen value of Cu from table 3.3 was found to be 1.241. It is higher than 1 and hence, it has strong effect on other factors in the cluster. The correlation coefficient 'r' of Principal Component Cu with more than 0.5 was considered to be highly statistically significant based its magnitude and not based on the ± sign and shown in Figure 6.

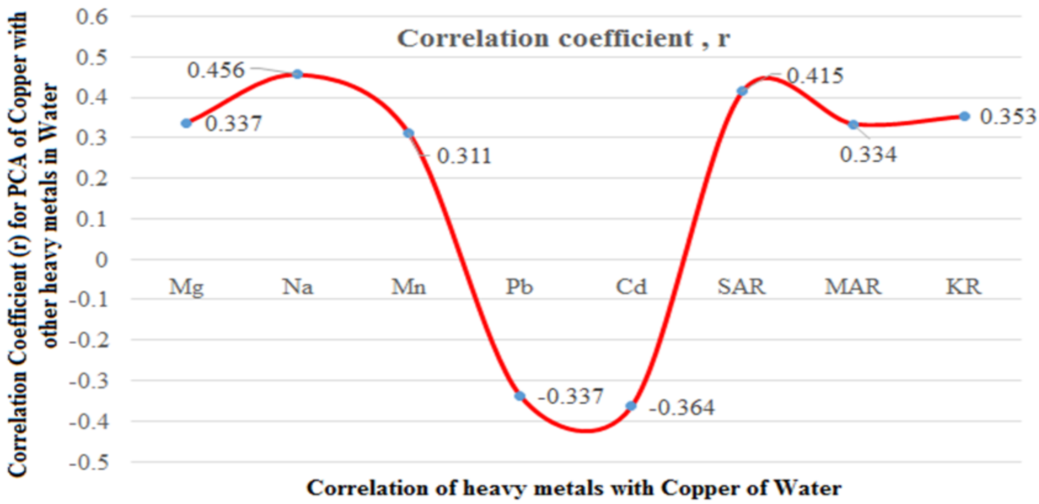

Figure-6. Variation of correlation coefficient of Copper in water with its clusters.

Figure 6 reveals the fact that the positive value of correlation coefficient shows the direct proportional relationship between the principal components Cu with other heavy metals in irrigation water. The direct proportional relationship with Cu was found for the factors like Mg, Na, Mn, SAR, MAR and KR. It means these factors will increase as Cu increases in the irrigation water. The minus sign of the correlation coefficient shows the inverse relationship between the principal components Cu with other factors. The inverse relationship with Cu was found for factors like Pb and Cd respectively. The values of r vary from -1 to 1. If the magnitude of the correlation coefficient r is > |±0.5|, it means there is high correlation between Cu and other variables considered. For instance, Na has the highest coefficient of correlation of 0.456, it means for every 1 ppm addition of Cu, there is 45.6% increase in Na in the water. The lowest coefficient of correlation of -0.364 is observed for Cadmium (Cd). It means that for every addition of 1mg/L of Cu there is 36.4% decrease of Cd content of irrigation water.

4. CONCLUSION AND RECOMMENDATIONS

This research article aimed to conduct a Study of heavy metals Variability and their effect on plant growth in Kanzenze River of Upper Akagera Catchment, Rwanda through the application of Principal Component Analysis (PCA) for sustainable irrigation in Rwanda. The study findings have demonstrated that Kanzenze Rive needs water treatment due to some heavy metals like Magnesium, Potassium, Zinc, Manganese, Cadmium and Chromium that fall out the permissible range prescribed by FAO guidelines. Based on PCA results, the cluster heavy metals like Calcium, Magnesium, Sodium and Copper contributed statistically significant a decreased their content in water while only factor like Potassium contributed statistically significant an increased content in irrigation water as far as factor loading increased by 1 ppm in water for irrigation. Therefore, water quality assessment is key determinant to be evaluated for proper irrigation to enhance crop productivity. It is proposed to policy makers, implementers, donors and any funding agencies with comparable curiosity to further take advantage of scaling up the water treatment amenities and produce more consciousness in order to realize perfection of living outcomes of remote families, particularly to counterbalance the effect of drought states which is principally Kanzenze Swamp of the Akagera Upper Catchment.

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