IMPACT OF NATURAL CAPITAL INVESTMENT STRATEGIES ON WATER QUALITY IN THE NDEMBERA RIVER SUB-CATCHMENT, TANZANIA

NORBERT J. NGOWI[1] & ADELAIDE E. SALLEMA[2]
[1]Institute of Development Studies, Mzumbe University, Tanzania
[2]Museum and House of Culture, National Museum of Tanzania, Tanzania

ABSTRACT

Natural capital investment strategies are a highly important tool in the sustainability of ecosystem services – including water and improved community livelihoods worldwide. However, their implications on the quality of water are hardly known in many societies of Tanzania. This paper reports the effect of one of such strategy, called Wetland Friendly Investment (WFI), on the quality of water on small parts of Ndembera sub-catchment of Tanzania, where (WFI) has been implemented for more than a decade. Samples of water were collected from the seven locations in the dry and wet seasons using 1,500 ml plastic tubes. Bottles with samples were labeled, stored in the cooling box and transported to the laboratory for analysis. All parameters were measured using standardized methods. To determine the effect of the strategy, we compared the measured mean difference values of the physicochemical properties of water before and after the introduction of the strategy using a two-way Analysis of Variance (ANOVA). The results showed that there was a statistically significant difference in Total Suspended Solids (TSS) before ($p = 0.0066$) and after ($p = 0.0324$) the intervention. Msugulika stream and the upstream of Ndembera River had the highest value for Ammonia-Nitrogen, with means of 0.3 and 0.23 mg/l in the dry and wet seasons, respectively. The use of agrochemicals was mentioned as one of the contributing factors in the poor quality of water and this could not significantly be reduced by the introduction of the WFI strategy alone. Therefore, more robust actions are required in addressing the issue of the quality of water in the sub-catchment.

Keywords: Ndembera River sub-catchment, physicochemical, wetlands friendly investment, natural capital.

1 INTRODUCTION

More than one billion people are depending on wetlands for ecosystem services – including water, fishing, agriculture, flood control and climate regulation [1]. The quality of water in this ecosystem is of paramount significance for society development. However, the degradation of wetlands is one of the major global problems [2] that has reduced the wetlands area cover by almost 50% in the past century therefore threatening the quality of water worldwide [3]. Various studies in Tanzania has identified changes in land use, over-use of water in irrigation, sedimentation, invasive alien species, and climate change to have contributed about degradation of 90% of the wetlands in the country [3], [4].

In the light of the growing pressure on the wetlands and the services they support, the Government of Tanzania has introduced a number of natural capital strategies – including the strategy called Wetlands Friendly Investment (WFI) in the 2000s [5]. Theoretically, supporting the local community with incentives would make them reduce pressure on these natural systems henceforth provision of the services to the society [6]. The main objective of the strategy was to balance the protection and utilization at the heart of the wise use concept. Despite the introduction of this strategy, little is known on the effect of its implementation on the quality of water in the areas implemented [7].

This study aimed to fill this gap by investigating the effect of the implementation of this strategy on the quality of water in Ndembera area, Tanzania. This area was selected

WIT Transactions on Ecology and the Environment, Vol 239, © 2019 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/WS190121

because the water in the basin supports many communities in Southern Tanzania, especially during the dry season when there is a water shortage. Data on the quality of water is important for developing proper land use as well as water treatment innovation methods in this catchment and beyond.

2 MATERIALS AND METHODS

2.1 The study area

This study was conducted in the section of Ndembera River Sub catchment which lies between latitudes 7°.57'.09" and 8° 13'.25" S and longitudes 35°05.16" and 35°37.49" E in Iringa District, Ngowi [3] (Fig. 1). It covers about 1,223 km^2 within the Great Ruaha River (GRR). The later drains an area of about 68,000 km^2. The climate is characterized by three distinct climatic zones – the highland, Midland and the lowland zone depending on the topography [3]. The long rain season runs between late March to June and the short ones November to February [8]. It is the only potential river contributing to about 500 m^3 of the total inflow to Ihefu wetlands [8]. The catchment is an important area for natural resources conservation [8]. Agriculture, fishing, and livestock keeping are the main economic activities in the study area.

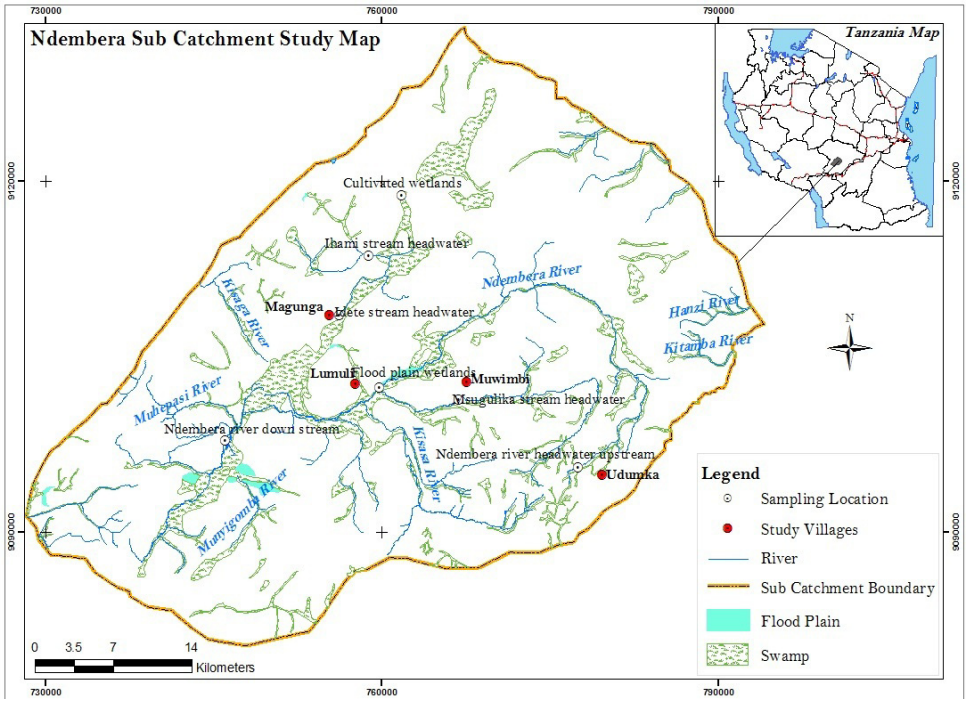

Figure 1: Map of the study area. Modified from Ngowi [3].

2.2 Methods

2.2.1 Sampling locations

Seven locations where the WFI strategy was introduced were selected. They included: cultivated wetlands, Ihemi stream, Ndembera, flood plain wetlands, Msugulika and Idete stream.

2.2.2 Collection of water samples

The water samples were collected from the depth of 15 cm in each of the seven locations in the month of September 2015 which represented the peak of the dry season and February 2016 for the wet season respectively. Water samples were stored in the 1500 ml clean corked plastic bottle that have been pre-washed with Nitric Acid and thoroughly rinsed with distilled water [9]. The sampling locations were selected based on ease of access and in such a way that the samples represent the entire sub catchment. The bottles with the sample were labelled SP_1, SP_2, SP_3, SP_4, SP_5, SP_6, and SP_7 based on the locations and kept in the cooling box, then transported to the laboratory for analysis.

2.2.3 Experimental design

Water quality analysis was carried out using standard analytical methods. Data were subjected to the Complete Randomized Design (CRD). ANOVA for each variable was conducted using MSTAT C software Program [10]. The mean values were separated by Duncan's Multiple Range Test (DMRT) to test for the significant difference at $p< 0.05$ [11].

2.2.4 Analysis of the quality of water

Water samples were filtered through a 5 µm glass fiber filter and analyzed for both physical and chemical characteristics including – temperature, pH, Electrical Conductivity (EC), Total Suspended Solids (TSS), Turbidity, Dissolved Oxygen (DO), Nitrate-Nitrogen (NO_3-N), Ammonia-Nitrogen (NH_4-N), Phosphate-Phosphorous (PO_4-P) and Total Alkalinity as $CaCO_3$ using standard method [12]. A transparent 30 cm plastic ruler was used to measure water depth. Odor, color, and temperature were measured using standard method [12] at the time of sampling. The temperature was measured using a thermometer. Distilled water was used to rinse the electrode between successive measurements. pH was determined using a pH meter (Toshniwal Instr. Pvt. Ltd No. 54) previously calibrated with a buffer solution with pH 7.0. Electrical Conductivity (EC) was determined using Systronics Conductivity Meter – 304 and recorded in micro Siemens per cm (µs/cm). Total Suspended Solids (TSS) was determined by filtering a known volume of sample through a thoroughly dried filter paper and the residue weighed in mg/l. The Total alkalinity was determined by the titration method and expressed as mg $CaCO_3$/l. Dissolved Oxygen (DO) was determined by Dissolved Oxygen meter, while Cadmium reduction method was used in the determination of Nitrate-nitrogen (NO_3-N). Ammonia-nitrogen (NH_4-N) was determined by Phenolnitroprusade method and Phosphate-phosphorous (PO_4-P) was determined by Ascorbic acid method.

3 RESULTS

The results obtained from the analysis are presented in Table 1 and detailed separately in the Appendices I and II of the supplemental information enclosed. The mean values of the physicochemical quality of water at the locations along different seasons are presented in Table 2 and Table 3 respectively.

Table 1: The physicochemical characteristics along the locations and the seasons.

		Physicochemical characteristics									
Location	Season	Temp °C	pH unit	EC µs/cm	TSS mg/l	Turbidity FAU	DO mg/l	NO_3-N mg/l	NH_4-N mg/l	PO_4-P mg/l	$CaCO_3$ mg/l
Cultivated wetlands	Dry	27.4	7.8	66	45	350	98	< 0.2	< 0.1	< 0.04	28
	Wet	23.0	7.52	94	30	30	6.49	0.000001	0.238	0.000009	32
Ihemi stream	Dry	28.5	7.8	72	17	500	95	< 0.2	< 0.1	< 0.04	30
	Wet	23.0	6.72	52	12	10	7.35	0.000001	0.200	0.000009	7
Ndembera down stream	Dry	28.5	7.3	75	20	550	55	< 0.2	< 0.1	< 0.04	33
	Wet	23.0	7.22	74	11	12	6.08	0.000001	0.2284	0.000005	43
Flood plain wetlands	Dry	29.0	8.3	82	17	45	50	< 0.2	0.2	0.15	36
	Wet	24.0	7.11	92	8	13	6.45	0.0000238	0.22111	0.000005	36
Msugulika stream	Dry	29.1	7.6	86	30	< 5	50	< 0.2	0.3	0.1	36
	Wet	25.0	7.50	82	13	0	5.94	0.000683	0.2276	0.000014	26
Ndembera upstream	Dry	29.2	6.6	135	0	55	5	< 0.2	0.3	0.06	55
	Wet	25.0	6.80	44	5	8	6.60	0.001394	0.2287	0.000014	13
Idete stream	Dry	28.8	7.1	250	7	350	5	< 0.2	< 0.1	0.08	225
	Wet	25.0	7.05	78	3	9	6.06	0.001512	0.2493	0.000024	40.40

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Table 2: Mean values of the physicochemical quality of water at each location.

	Physicochemical characteristics								
Location	pH unit	EC µs/cm	TSS mg/l	Turbidity FAU	DO mg/l	NO_3-N mg/l	NH_4-N mg/l	PO_4-P mg/l	$CaCO_3$ mg/l
Cultivated wetlands	7.650	80.000	37.500	190.000	52.250	0.050	0.100	0.000	30.000
Ihemi stream	7.250	62.000	14.500	255.000	51.200	0.050	0.100	0.000	18.500
Ndembera downstream	7.250	74.500	15.500	281.000	30.550	0.050	0.100	0.000	38.000
Flood plain wetlands	7.000	87.000	12.500	29.000	28.250	0.050	0.200	0.100	36.000
Msugulika stream	7.550	84.000	21.500	2.000	27.950	0.050	0.250	0.050	31.000
Ndembera upstream	6.700	89.500	2.500	31.500	5.800	0.050	0.250	0.050	34.000
Idete stream	7.050	164.000	5.000	179.500	5.550	0.050	0.200	0.050	132.700

Table 3: Mean values of the quality of water along dry and wet seasons.

	Physicochemical characteristics								
Season	pH unit	EC µs/cm	TSS mg/l	Turbidity FAU	DO mg/l	NO_3-N mg/l	NH_4-N mg/l	PO_4-P mg/l	$CaCO_3$ mg/l
Dry	7.500	109.429	19.429	264.857	51.143	0.100	0.129	0.071	63.286
Wet	7.114	73.714	11.714	11.714	6.443	0.000	0.214	0.000	28.200

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The mean dry season values of pH (7.500), EC (109.429 mg/l), TSS (19.429 mg/l), turbidity (264.857 FAU), DO (51.143 mg/l), NO_3-N (0.100 mg/l), PO_4-P (0.071 mg/l) and total alkalinity as $CaCO_3$ (63.286 mg/l) were higher than those of the wet season Table 3.

Results from ANOVA show that there was a significant variation of the physicochemical characteristics of the TSS in all locations (Table 4) and the seasons. Also Turbidity, DO and $P0_4$-P showed a significant difference in all the seasons with a p-value of 0.0246, 0.0190 and 0.0465 respectively (Table 5).

Table 4: Separated mean values of the TSS at sampling locations.

	Sampling locations						
	Cultivated wetlands	Ihemi stream	Ndembera down stream	Flood plain wetlands	Msugulika stream	Ndembera up stream	Idete stream
Mean value	35.5^a	14.5^b	15.5^b	12.5^b	21.5^c	2.5^d	5.0^d

Note: Mean values superscripted by different lower-case letter in the same row are significantly different following a separation by Duncan's Multiple Range Test (DMRT) at P value < 0.05.

Table 5: Separated mean values of the TSS, Turbidity, DO and $P0_4$-P across the dry and wet seasons.

	Physicochemical characteristics			
Season	TSS mg/l	Turbidity (FAU) mg/l	DO (% of saturation) mg/l	PO_4-P mg/l
Dry	19.429^a	264.857^a	51.143^a	0.071^a
Wet	11.714^b	11.714^b	6.443^b	0.000^b

Note: Mean values superscripted by different lower-case letter in the same column are significantly different following a separation by DMRT at P < 0.05.

4 DISCUSSION

Some marked variations of the quality water were observed along locations and the seasons. The water temperature had a range of 23°C to 29.2°C. The low water temperature (23°C) of the sub-catchment during the wet season could be a result of seasonal changes in air temperatures associated with the cold season experienced in the Southern Highlands of Tanzania during the wet season [13]. This temperature is within the range of 10°C–50°C for rivers in the tropical waters [12].

The higher mean values obtained at the dry season for pH, EC, TSS, turbidity, DO, NO_3-N, PO_4-P and total alkalinity could be caused by the reduced volume of water from major streams in the area. A similar trend was observed for Katogora wetlands in Nigeria [9]. EC of water varied slightly among and within the locations. This shows that water in the study area contained similar dissolved nutrients that are responsible for carrying electric current. The highest value recorded 164.000 µs/cm at Idete stream may be attributed to wetlands being bisected by road and closer to settlement areas thus vulnerable to pollution. Gongden and Lohdip [14] show that surface water is very vulnerable to pollution due to its ease of accessibility to human influence while the SMUWC [13] reported EC of waters in other sub catchment of the Southern Highlands Tanzania have a high capacity for electric currents that do not vary significantly.

Nitrate – Nitrogen concentrations are mostly low (0.1mg/l) beyond the detection limit for the analysis. Ammonia – Nitrogen results show a similar pattern. Samples collected at

Msugulika, Ndembera upstream and in the cultivated wetlands show higher levels of Nitrogen.

The low mean values for PH (7.250 units), EC (74.500 µs/cm), DO (30.550 mg/l), NO_3-N (0.050 m/l), $P0_4$ (0.000 mg/l) and total alkalinity (38.000 mg/l) obtained after the intervention could be one of the positive effects of the strategy. The SMUWC [13] observed higher mean values for the similar parameters in the catchment. However, higher mean values for TSS (15.500 mg/l), Turbidity (281.000 FAU) and NH_4-N (0.100mg/l) have been recorded at Ndembera downstream after the intervention. This could be caused by the effect of use of agrochemicals – including fertilizer in the wetland's cultivation, thus fluctuations of these parameters in the area.

5 CONCLUSION

The results showed that most of the physicochemical properties of water in the study area remained broadly similar despite the intervention. This shows that the strategy alone had not greatly changed the quality of water in the area and that human-related factors such as changing land uses, use of fertilizer, runoff from farmlands, and animal grazing are among contributing factors in the poor quality of water.

ACKNOWLEDGEMENTS

Authors are grateful to Mzumbe University and the Self Steering Sustainable Social Innovation through Training and E-Research (4SITe) Programme for financial support. In addition, Mr. Revocatus Mtaki of Mkwawa University College of Education during the data analysis is gratefully acknowledged.

APPENDIX I
RESULTS OF THE ANALYSIS OF WATER SAMPLES

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Function: ANOVA - 2
Data case 1 to 14
Two-way Analysis of Variance over
Variable 1 (Sampling point/location) with values from 1 to 7 and over
Variable 2 (Season) with values from 1 to 2.

Variable 3: pH - A N A L Y S I S    O F    V A R I A N C E    T A B L E

                Degrees of   Sum of
  Source          Freedom    Squares     Mean Square    F-value   Prob
  Location           6          1.54          0.257      1.75    0.2575
  Season             1          0.52          0.521      3.53    0.1092
  Error              6          0.88          0.147
  Total             13          2.95
Grand Mean= 7.307 Grand Sum= 102.300 Total Count= 14. Coefficient of
Variation = 5.25%. Means for variable 3 (pH) for each level of variable 1
(Sampling point):-----------------------------------------------------
  Var 1 value         1      2      3      4      5      6      7
  Var 3 Mean          7.65   7.25   7.25   7.70   7.55   6.70   7.05
     ------------------------------------------------------------------
Means for variable 3 (pH) for each level of variable 2 (Season):
      Var 2      Value              1             2
      Var 3       Mean             7.50          7.114
     lsd at 0.05 alpha level =     0.502

Variable 4: EC - A N A L Y S I S    O F    V A R I A N C E    T A B L E

                Degrees of   Sum of
```

Source	Freedom	Squares	Mean Square	F-value	Prob
Location	6	13256.43	2209.405	0.88	0.5614
Season	1	4464.29	4464.286	1.77	0.2315
Error	6	15118.71	2519.786		
Non-additivity	1	10862.91	10862.913	12.76	0.0160
Residual	5	4255.80	851.160		
Total	13	32839.43			

Grand Mean= 91.571 Grand Sum= 1282.000 Total Count= 14. Coefficient of Variation= 54.82%. Means for variable 4 (EC) for each level of variable 1 (Sampling point):

Var 1 values	1	2	3	4	5	6	7
Var 4 Mean	80.0	62.0	74.5	87.0	84.0	89.5	164.0

Means for variable 4 (EC) for each level of variable 2 (Season):

Var 2	Value	1	2
Var 4	Mean	109.429	73.714

lsd at 0.05 alpha level = 65.655

Variable 5: TSS - A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Location	6	1618.43	269.738	9.95	0.0066
Season	1	208.29	208.286	7.68	0.0324
Error	6	162.71	27.119		
Total	13	1989.43			

Grand Mean= 15.571 Grand Sum= 218.000 Total Count= 14. Coefficient of Variation= 33.44%. Means for variable 5 (TSS)for each level of variable 1 (Sampling point):

Var 1 value	1	2	3	4	5	6	7
Var 5 Mean	37.5	14.5	15.5	12.5	21.5	2.5	5.0

Means for variable 5 (TSS)for each level of variable 2 (Season):

Var 2	Value	1	2
Var 5	Mean	19.429	11.714

lsd at 0.05 alpha level = 6.811

Variable 6: TURBIDITY - A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Location	6	160565.86	26760.976	1.06	0.4726
Season	1	224284.57	224284.571	8.89	0.0246
Error	6	151452.43	25242.071		
Total	13	536302.86			

Grand Mean= 138.286 Grand Sum = 1936.000 Total Count= 14. Coefficient of Variation = 114.89%. Means for variable 6 (TURBIDITY) for each level of variable 1 (Sampling point):

Var 1 value	1	2	3	4	5	6	7
Var 6 Mean	190.0	255.0	281.0	29.0	2.0	31.5	179.5

Means for variable 6 (TURBIDITY)for each level of variable 2 (Season):

Var 2	Value	1	2
Var 6	Mean	264.857	11.714

lsd at 0.05 alpha level = 207.801

Variable 7: DO - A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Location	6	4250.62	708.437	1.03	0.4883
Season	1	6993.32	6993.315	10.12	0.0190

```
  Error              6        4145.71        690.952
  Total             13       15389.65
Grand Mean= 28.793 Grand Sum= 403.100.  Total Count= 14. Coefficient of
Variation=   91.29%. Means for variable 7 (DO)for each level of variable 1
(Sampling point):-------------------------------------------------------
  Var 1 value    1          2      3      4      5      6      7
  Var 7 Mean     52.25      51.2   30.55  28.25  27.95  5.8    5.55
      ------------------------------------------------------------------
Means for variable 7 (DO)for each level of variable 2 (Season):
      Var 2     Value      1               2
      Var 7     Mean       51.143          6.443
     lsd at 0.05 alpha level =     34.380
```

Variable 8: NO_3-N - A N A L Y S I S O F V A R I A N C E T A B L E

```
                Degrees of   Sum of
  Source          Freedom    Squares     Mean Square    F-value   Prob
  Location           6          0.00          0.000
  Season             1          0.04          0.035
  Error              6          0.00          0.000
  Total             13          0.04
Grand Mean= 0.050    Grand Sum = 0.700 Total Count= 14. Coefficient of
Variation = 0.00%. Means for variable 8 (NO3-N)for each level of variable 1
(Sampling point):-------------------------------------------------------
  Var 1 value         1      2      3      4      5      6      7
  Var  Mean           0.05   0.05   0.05   0.05   0.05   0.05   0.05
      ------------------------------------------------------------------
Means for variable 8 (NO3-N) for each level of variable 2 (Season):
      Var 2     Value   1            2
      Var 8     Mean    0.100        0.000
     lsd at 0.05 alpha level =      0.000
```

Variable 9: NH_4-N - A N A L Y S I S O F V A R I A N C E T A B L E

```
                Degrees of   Sum of
  Source          Freedom    Squares     Mean Square    F-value   Prob
  Location           6          0.06          0.010      0.91    0.5435
  Season             1          0.03          0.026      2.40    0.1723
  Error              6          0.06          0.011
  Total             13          0.15
Grand Mean= 0.171 Grand Sum= 2.400 Total Count= 14. Coefficient of Variation
= 60.38%. Means for variable 9 (NH4N for each level of variable 1 (Sampling
point):-----------------------------------------------------------------
  Var 1 value         1      2      3      4      5      6      7
  Var 9 Mean          0.1    0.1    0.1    0.2    0.25   0.25   0.2
      ------------------------------------------------------------------
Means for variable 9 (NH4N)for each level of variable 2 (Season):
      Var 2      Value    1          2
      Var 9     Mean    0.129        0.214
     lsd at 0.05 alpha level =      0.135
```

Variable 10: PO_4 - A N A L Y S I S O F V A R I A N C E T A B L E

```
                Degrees of   Sum of
  Source          Freedom    Squares     Mean Square    F-value   Prob
  Location           6          0.02          0.003      1.00    0.5000
  Season             1          0.02          0.018      6.25    0.0465
  Error              6          0.02          0.003
  Total             13          0.05
Grand Mean= 0.036    Grand Sum= 0.500 Total Count=  14. Coefficient of
Variation = 149.67%. Means for variable 10 (PO4)for each level of variable 1
(Sampling point):-------------------------------------------------------
```

Var 1 value	1	2	3	4	5	6	7
Var 10 Mean	0.00	0.0	0.0	0.1	0.05	0.05	0.05

Means for variable 10 (PO4)for each level of variable 2 (Season):

Var 2	Value	1	2
Var 10	Mean	0.071	0.000

lsd at 0.05 alpha level = 0.070

Variable 11: $CaCO_3$ - A N A L Y S I S O F V A R I A N C E T A B L E

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob
Location	6	18123.35	3020.559	1.30	0.3805
Season	1	4308.53	4308.526	1.85	0.2228
Error	6	13984.55	2330.759		
Non-additivity	1	12291.86	12291.862	36.31	0.0018
Residual	5	1692.69	338.538		
Total	13	36416.43			

Grand Mean = 45.743 Grand Sum = 640.400 Total Count = 14. Coefficient of Variation= 105.54%. Means for variable 11 (CaCO3) for each level of variable 1 (Sampling point):

Var 1 value	1	2	3	4	5	6	7
Var 11 Mean	30.00	18.50	38.0	36.0	31.0	34.0	132.7

Means for variable 11 (CaCO3)for each level of variable 2 (Season):

Var 2	Value	1	2
Var 11	Mean	63.286	28.200

lsd at 0.05 alpha level = 63.144

APPENDIX II
SEPARATED MEAN VALUES BY DUNCAN'S MULTIPLE RANGE TEST AT ALPHA < 0.050

Variable 5: TSS/TDS

Means for variable 5 (TSS) for each level of variable 1 (Sampling point):

Var 1, values	1	2	3	4	5	6	7
Var 5, Mean	37.5A	14.5B	15.5B	12.5B	21.5C	2.5D	5.0D

Means for variable 5 (TSS/TDS) for each level of variable 2 (Season):

Var 2 Value	Var 5 Mean	
1	19.429	A
2	11.714	B

Variable 6: Turbidity

Means for variable 6 (TURBIDITY) for each level of variable 2 (Season):

Var 2 Value	Var 6 Mean	
1	264.857	A
2	11.714	B

Variable 7: DO

Means for variable 7 (DO) for each level of variable 2 (Season):
Duncan's Multiple Range Test at alpha 0.050

Var 2 Value	Var 7 Mean	
1	51.143	A
2	6.443	B

Variable 10: PO_4

Means for variable 10 (PO4) for each level of variable 2 (Season):

Var 2 Value	Var 10 Mean	
1	0.071	A
2	0.000	B

REFERENCES

[1] Ramsar Convention on Wetlands, FAO, International Water Management Institute (IWMI), *Wetlands and Agriculture: Partners for Growth,* Gland: Ramsar Convention on Wetlands; Rome: FAO; Colombo: IWMI, pp. 1–16, 2014.

[2] Gray, M.J., Hagy, H.M., Nyman, J.A. & Stafford, J.D., Management of wetlands for wildlife. *Wetlands Techniques,* eds J.T. Anderson & C.A. Davis. DOI: 10.1007/978-94-007-6907-6-4, 2013.

[3] Ngowi, N.J., Contribution of wetland friendly investment approach on livelihoods and ecosystem services: The case of Ndembera River in Iringa, Tanzania. PhD thesis, University of Dar es Salaam, 2018.

[4] United Republic of Tanzania (URT), Fifth National Report on the Implementation of the Convention on Biological Diversity, The Vice President's Office, Dar es Salaam, 2014. www.cbd.int/doc/world/tz/tz-nr-05-en.pdf.
[5] Ministry of Natural Resources and Tourism (MNRT), Sustainable Wetlands Management Programme Completion Report, Dar es Salaam, 2013.
[6] Ngowi, N.J. & Mwakaje, A.G., Implementation effects of incentive policies on Tanzanian wetland ecosystems. *Kasetsart Journal of Social Science.* DOI: 10.1016/j.kjss.2018.05.016, 2018.
[7] Ernst & Young, Value for money audit for participatory forest anagement and sustainable wetlands management programme. Dar es Salaam, Tanzania, p 34, 2010. http://um.dk/en/~/media/um/english-site/documents/danida/eval/987-87-7087-472-4/201005annex4tanzaniacasestudy.ashx.
[8] Rufiji Basin Water Board (RBWB), *Environmental and Social Impact Assessment Lugoda & Maluluma Hydropower on Ndembera River.* Environmental and Social impact assessment report. Vol 1 – report. ecoVision GmbH, Austria, pp. 275, 2015.
[9] Ibrahim, B.U., Auta, J. & Balogu, J.K., An assessment of the physico-chemical parameters of Kantagora reservoir, Niger State, Nigeria. *Bayero Journal of Pure and Applied Sciences,* **2**(1), pp. 64–69, 2009.
[10] Freed, R., Eisensmith, S.P., Goetz, S., Reicosky, D., Smail, V.M. & Wolleberg, P., *MSTAT-C A Microcomputer Program for the Design, Management and Analysis of Agronomic Research Experiments*, Michigan State University, USA, 1990.
[11] Steel, R.G.D. & Torrie, J.H., *Principle and Procedures of Statistics*, McGraw-Hill: New York, 633 pp., 1980.
[12] World Health Organization (WHO), *Guidelines for Drinking Water Quality*, Geneva, 211 pp., 1984.
[13] Sustainable Management of the Usangu Wetland and its Catchment (SMUWC), Water Quality Assessment Report, 39 pp., 2001.
[14] Gongden, J.J. & Lohdip, Y.N., Seasonal variation of the surface water quality of two dams in Plateau State, north central Nigeria. *Water Resources Management VIII*, ed. C.A. Brebbia, *WIT Transactions of Ecology and Environment*, vol. 196, WIT Press: Southampton and Boston, pp. 291–298, 2015.