

Effects of Land Use on Spring and Streamflow Quality in River Malaget Sub-Catchment, Kericho County, Kenya

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Abstract Various studies have found that effects of land use on water quality are attributable to about 80 % of diseases in the developing world. The study's main objective was to evaluate the effects of land use on spring and streamflow quality in River Malaget sub-catchment. Thirty-three sampling points were selected by stratified sampling, i.e., ten springs and one river point per agro-ecological zones, namely: Tea-Dairy-Forest Zone, Wheat-Maize-Barley Zone and Marginal Coffee Zone. Water samples from each zone were tested on site for temperature, pH, turbidity, electrical conductivity, DO, and total dissolved solids. BOD, *E.coli*, fluorides, total hardness, nitrates, nitrites, ammonia and phosphates were tested in the laboratory. Pillai's trace in MANOVA, revealed a significant variability in the distribution of water quality parameters in relation to land use as the means of the three agro-ecological zones were significantly different, $V = 1.535$, $F(20, 44) = 7.262$, $p < .05$. Univariate ANOVAs on each of the variables revealed significant effect on temperature, $F(2, 30) = 4.833$, $p > .05$; electrical conductivity, $F(2, 30) = 14.730$, $p > .05$; turbidity, $F(2, 30) = 3.600$, $p > .05$; and nitrates, $F(2, 30) = 5.879$, $p > .05$. In conclusion, indeed, land use has had an impact on streamflow and spring water quality in the study area. It is recommended that water is treated before drinking and all springs are protected fully against contamination.

Keywords: water quality parameters, ArcGIS, MANOVA, agro-ecological zones, River Malaget Sub-catchment, springs

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1. Introduction

Unsafe drinking water and unimproved sanitation is linked to nearly 80% of all reported cases of diseases in developing world [1], which is 4.6 billion diarrhoea episodes annually [2]. Therefore, safe drinking water will lower the burden of infection related to consumption of contaminated water and hence increasing life expectancy. According to [3], more than 1.1 billion people use unimproved water sources and almost 2 million deaths are by diarrhoea, out of 3 million people dying yearly from water-related infections. Majority of those affected are children due to the ingestion of water contaminated by faecal matter due to inadequate sanitation and hygiene.

One of the sources of water pollution is advanced agriculture which depends on the addition of farm chemicals such as fertilizers and manures in order to improve crop yields [4]. Poorly managed application of farm chemicals and improper human waste disposal, may lead to their being washed away by run-off during rainy seasons and deposited in springs, posing a major environmental and public health concern. Conceptualization of water movement through a catchment is crucial in understanding the effects of land

use on water quality [5]. In as far as water quality is concerned; land use is the source of contaminants while the hydrology is the transporter, as materials are cycled among different ecosystems [6].

Water scarcity and pollution are major challenges to sustainable water resources management in Africa. Apparently, water pollution due to land use in various sources has been increasing over recent decades in most countries [7]. Reference [8], in a study in South Africa, found that majority of rural dwellers are in danger due to unsafe drinking water. According to [7], only 54% of the Tanzanian population has access to improved water supplies with 24% having adequate sanitation.

According to [9], 80% of Kenya is arid and semi - arid land and the rest experiences water scarcity due to catchment degradation resulting from land use. Water pollution is a result of catchment degradation which is related to runoff of farm chemicals and human wastes. Reference [10] noted that land use may impact negatively on the water quality in the surroundings and reduce its availability. Hence, it is clear that land use such as agriculture and settlement may negatively impact on water quality.

In River Malaget sub-catchment, farm chemicals such as manure and synthetic fertilizers are used to improve farm yields due to diminishing fertility owing to

continuous farming. In addition, 93.7 % of households use pit latrines due to lack of water and sewerage services [11]. Substances from these land use may be flushed by run-off into local water sources. Evaluating the effects of land use on water quality is important so as to check certain public health and environmental issues.

River Malaget sub-catchment is located within Chilchila ward which has 82.9 % of households with unimproved water sources, being one of the highest numbers in Kericho County [11]. The disparity in access to improved sanitation amongst wards in the County is over 80 % [12]. Majority of the locals are farmers and rely on spring and streamflow water sources for drinking [11]. Moreover, due to diminishing fertility owing to continuous farming, the soil requires addition of fertilizers and manure [13]. Much of the cultivated land is on steep slopes which are largely hydrologically sensitive areas (HSA) and are at risk, as farm chemicals and settlement wastes may find their way into water sources during rainstorms, and introduce nutrients such as nitrates and phosphates into them. If application of farm chemicals is poorly managed and waste disposal is not properly done, it may lead to detrimental effects to humans.

Many studies have concentrated on the quality of streamflow water and other ground water sources besides springs, for instance, [[14] ; [15]] and so on. This study will contribute to existing knowledge on springs which are essentially ground water sources exposed to the surface and may be threatened by external factors like agriculture and settlement. Furthermore, comparing the water quality of springs and streamflow will reveal the interaction between surface water and ground water. In addition to physico- chemical parameters that most studies have dwelt on, it seeks to test for biological water quality indicators which are important in determining the sanitation level. Further, it will demonstrate the relationship between hydrology and transport of contaminants [6].

2. Materials and Methods

2.1. Location of the Study

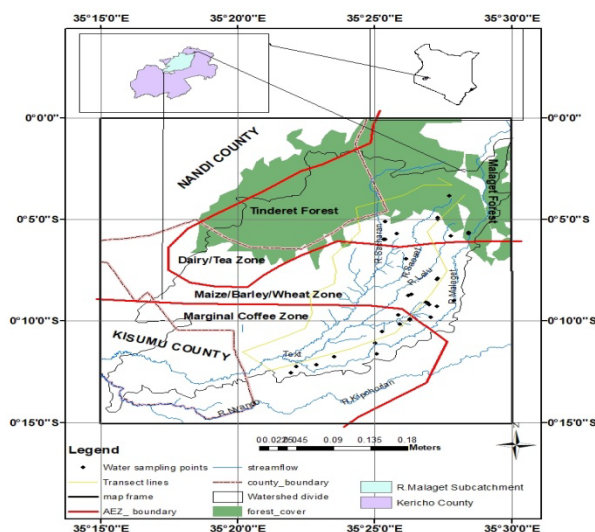


Figure 1. Map Showing River Malaget Sub-catchment, Kericho County-Kenya (Adopted from Survey of Kenya, 1972)

The study area is 359.14 km² and is located between 35°20' E and 35°30' E and 0°00'S and 0°20'S in Kericho County [13,16]. The area borders the Tinderet Forest to the North and Londiani Hills to the East and covers Kamasian and Chilchila Wards [11,16].

2.1.1. Climate

Climate is majorly driven by the inter-tropical convergence zone (ITCZ), modified by local relief effects. Rainfall pattern is bimodal with a long rainy season between the months of March and July, and a short rainy season between September and December. It receives an average rainfall of between 1100 and 1400 mm annually on a normal year. Mean daily temperature is between 15° and 20° C [13,17].

2.1.2. Hydrology and Water Resources

The landscape is highly rugged due to volcanic activity and faulting while altitude is around 2600 m above sea level. The drainage varies with topography and the general flow of rivers is southwest wards forming a fault-guided drainage pattern. River Lelu feeds River Sacharan which, together with River Saoset, joins River Malaget, a tributary of the River Nyando. These rivers fall in the larger Lake Victoria South Catchment Area [13,16,17,18].

2.1.3. Geology and Hydrogeology

Geologically, intermediate and basic volcanic rocks such as phonolitic nephelinites with intercalated tuffs underlie most of the area. On plateau and upper-level upland transitions especially at the South of Tinderet are tuffs, ashes, other pyroclastic rocks and agglomerates from recent volcanoes. Rocks found around the Fort Ternan tunnel station are derived from Koru Beds specifically of the Lower Miocene Age. All these are rock formations of the Tertiary period [13,16,18].

River Malaget sub- catchment is located within two major parallel fault lines with volcanic vents at Tinderet and Limutet. Groundwater occurrence here is associated with two related types of aquifers: volcanic rock types with primary porosity, and faults and fracture zones. Hence, the springs in the area are likely to be of lava and fault / fracture types. The two types of aquifers may vary considerably in thickness and are usually subject to seasonal fluctuations of groundwater level. Borehole 2 at Tinderet indicates a water-table perched on the Tinderet lavas interbedded with sediments, but no geophysical findings exist to show the depth [16,17].

2.2. Research Design

2.2.1. Sampling of Springs and River Points

Stratified sampling technique was employed, whereby the sampling sites were selected and placed into 3 strata of land use categories. Springs and river sampling points close to potential sources of contaminants were selected and captured under the three agro- ecological zones in the area. These are Tea-Dairy Zone, Wheat/Maize/Barley Zone and Marginal Coffee Zone [13] which reflect the land use. 10 springs and 1 point along the River Malaget were selected from each stratum to ensure that the 3 agro-ecological zones are represented.

2.2.2. Water Sampling

Given that the study was interested in water quality variation within the wet and dry seasons, samples were collected in two different sessions per season. Water sampling for the dry season was done in December, 2016 and February, 2017 and for the wet season it was done in April, 2017 and June, 2017. The process of sample collection was done between 9 am and 12 noon as this gave enough time for these samples to be rushed and delivered to the laboratory in Egerton University by 2 pm for the analysis.

Water quality parameters such as pH, DO, TSS, electrical conductivity and temperature were determined on site using a portable universal field meter while turbidity were measured by a turbidimeter [23]. Water samples for BOD, faecal coliforms, fluoride, nitrates and phosphates were collected in plastic bottles to minimize sample alteration after which, they underwent laboratory analysis [24]. The samples were drawn directly from the spring pools and the 3 points along the river, after rinsing the sterilized sample bottles with the water to be sampled. Samples for chemical analysis were stored in room temperature, while samples for microbiological tests were stored in dry ice at 4°C to await laboratory analysis within 48 hours along with others [19].

3. Results and Discussion

3.1. Water Quality Results

Statistical presentation of the results is provided in the form of comparative bar graphs. The parameters were tested within the dry and wet seasons in the study area.

3.1.1. Phosphates

The observed values of phosphates in the River Malaget Sub-catchment ranged from 0.004 mg/l to 0.037 mg/l in the dry season and from 0.002 mg/l to 0.037 mg/l in the wet season. There is very minimal variation in the concentration of phosphates within the two seasons. The overall mean value for phosphates in the sub-catchment was 0.013 mg/l. The phosphate values for both the springs and streamflow were within the limits of < 30 mg/l for drinking water as recommended by both [21] and [22] guidelines.

3.1.2. Nitrates

The observed values of nitrates in the River Malaget Sub Catchment ranged from 5.48 mg/l to 32.53 mg/l. There is very slight variation in the concentration of nitrates from the dry season to the wet season. The overall mean value for nitrates in the sub-catchment was 19.13 mg/l. The nitrate values for both the springs and streamflow were within the limits of < 10 mg/l and < 50 mg/l for drinking water as recommended by both [21] and [22] guidelines, respectively.

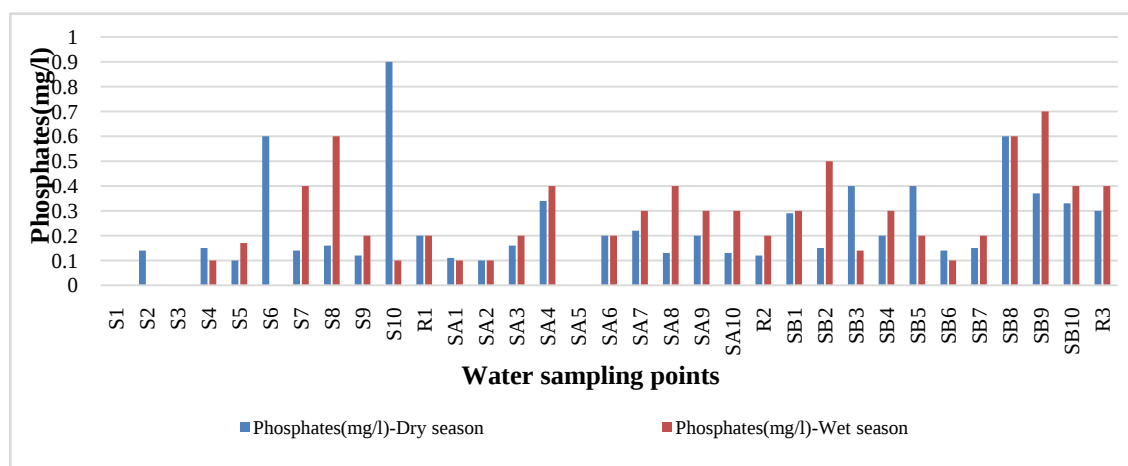


Figure 2. Mean of Phosphates in the Agro-ecological zones

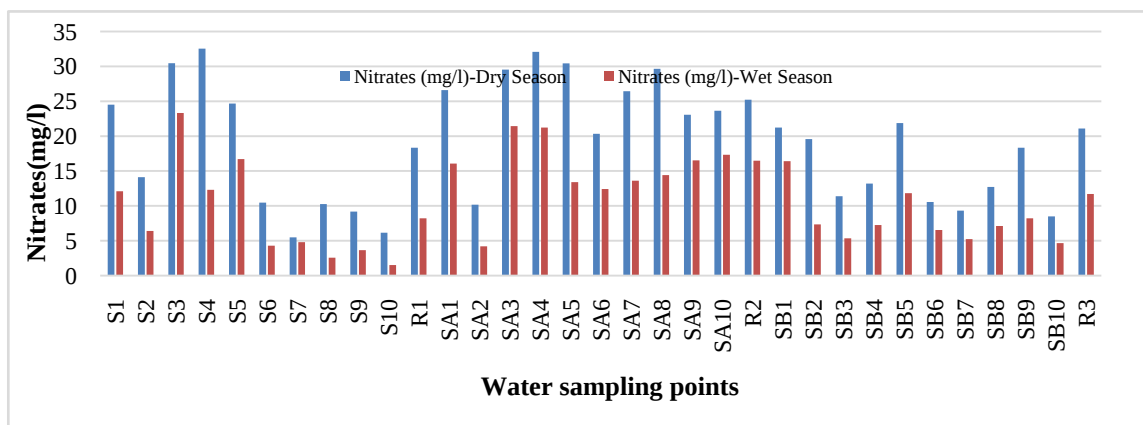


Figure 3. Mean of nitrates in the Agro-ecological zones

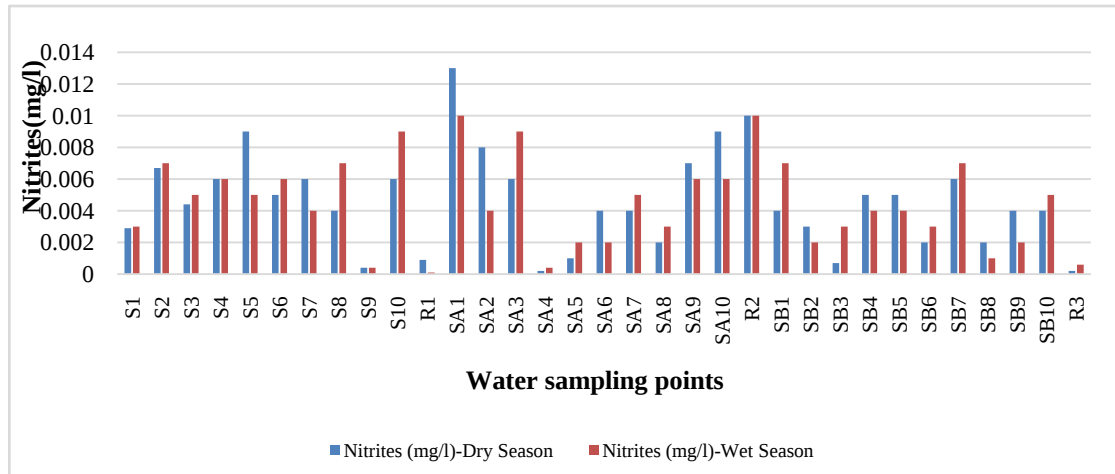


Figure 4. Mean nitrites of the Agro-ecological zones

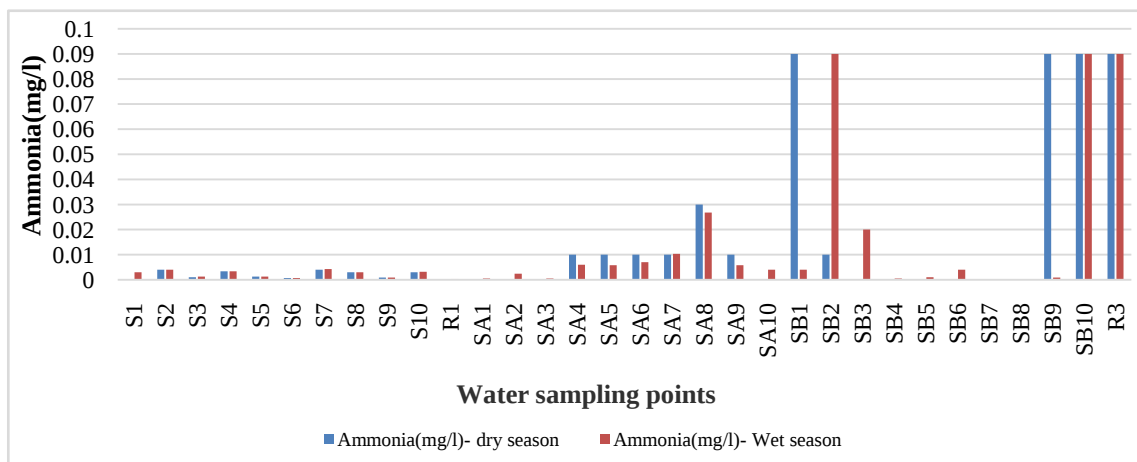


Figure 5. Mean ammonia of the Agro-ecological zones

3.1.3. Nitrites

The observed values of nitrites in the River Malaget Sub Catchment ranged from 0 mg/l to 0.013 mg/l in the wet season and from 0.0004 mg/l to 0.013 mg/l in the dry season. The overall mean value for nitrites in the sub-catchment was 0.007 mg/l. The nitrite values for both the springs and streamflow were within the limits of < 3 mg/l for drinking water as recommended by both [21] and [22] guidelines.

3.1.4. Ammonia

The observed values of ammonia in the River Malaget Sub Catchment ranged from - 0 mg/l to 0.09 mg/l in both the dry season and from 0.001 mg/l to 0.09 mg/l in the wet season. This indicates a very negligible difference in ammonia concentrations between the two seasons. The overall mean value for ammonia in the sub-catchment was 0.014 mg/l.

No guideline value has been set for ammonia by WHO as it is not directly important for health in the expected concentrations in drinking water, which is usually below 0.2 mg/l of ammonia [22]. However, [21] has set a limit of 0.05 mg/l of which all samples were found to be within.

3.1.5. Electrical Conductivity

The observed values of electrical conductivity in the River Malaget Sub Catchment ranged from 93 μ S/cm to

654 μ S/cm in the dry season and from 21 μ S/cm to 631 μ S/cm in the wet season. This indicates a very small difference in the electrical conductivity concentration between the two seasons.

The values for both the springs and streamflow were within the limits of < 1200 μ S/cm and < 2000 μ S/cm for drinking water as recommended by both [21] and [22], respectively. Electrical conductivity of water is influenced by the presence of various inorganic dissolved solids such as chlorides, nitrates, nitrites, sulphates, phosphates and metals like Aluminium, Iron, Calcium, Sodium and Magnesium. It is a function of temperature, types and concentration of ions and total hardness.

3.1.6. Total Suspended Solids (TSS)

The observed values of TSS in the River Malaget Sub-catchment ranged from 0 mg/l to 3.40 mg/l in both the dry season and from 16.24 mg/l to 80.2 mg/l in the wet season. It appears from the results that generally TSS levels are higher in the wet season compared to the dry season. The possible explanation to this is run off incidences during the wet season, which introduce pollution in the form of suspended solids. The TSS values in the dry season, for all the water sampling points were within the limits of < 30 mg/l for drinking water as recommended by both [21] and [22], respectively. However, during the wet season, about a third of these sampling points had TSS levels that exceeded the recommended levels.

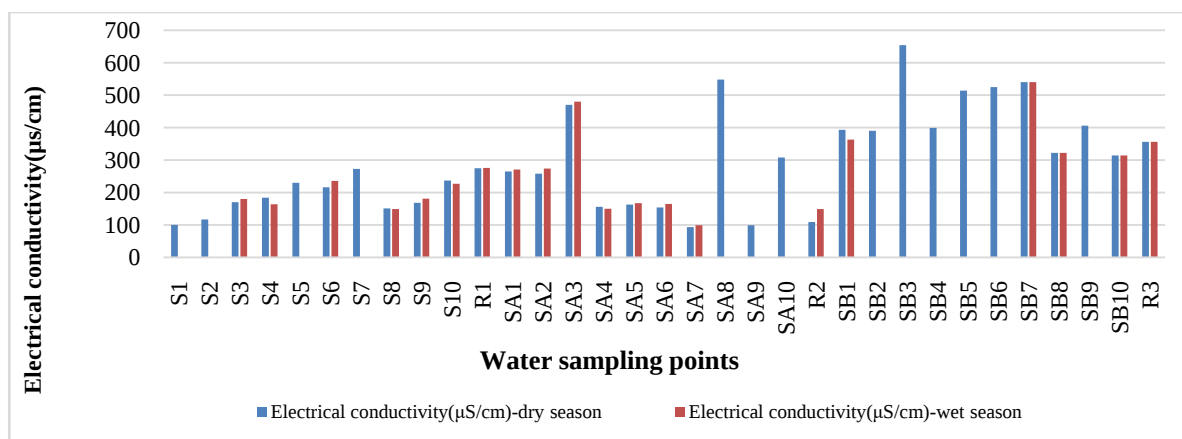


Figure 6. Mean electrical conductivity of the Agro-ecological zones

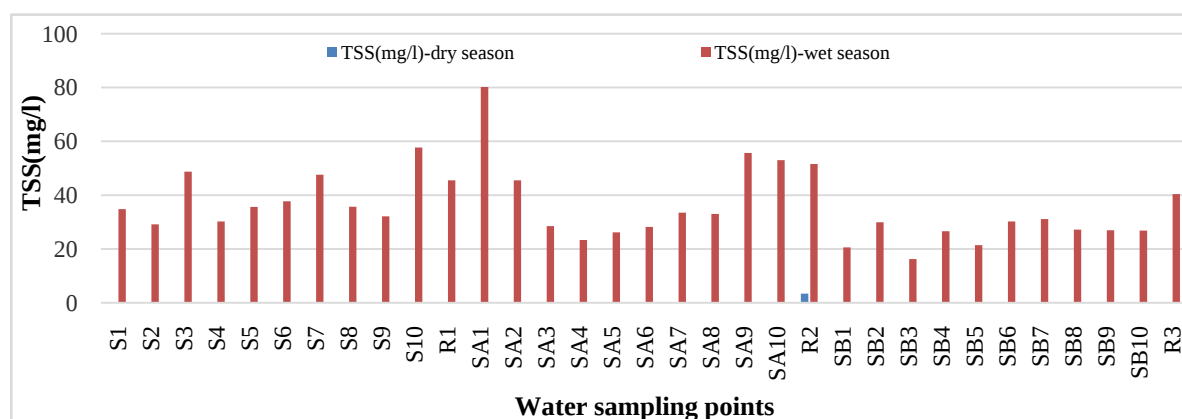


Figure 7. Mean TSS values for the 3 Agro-ecological zones

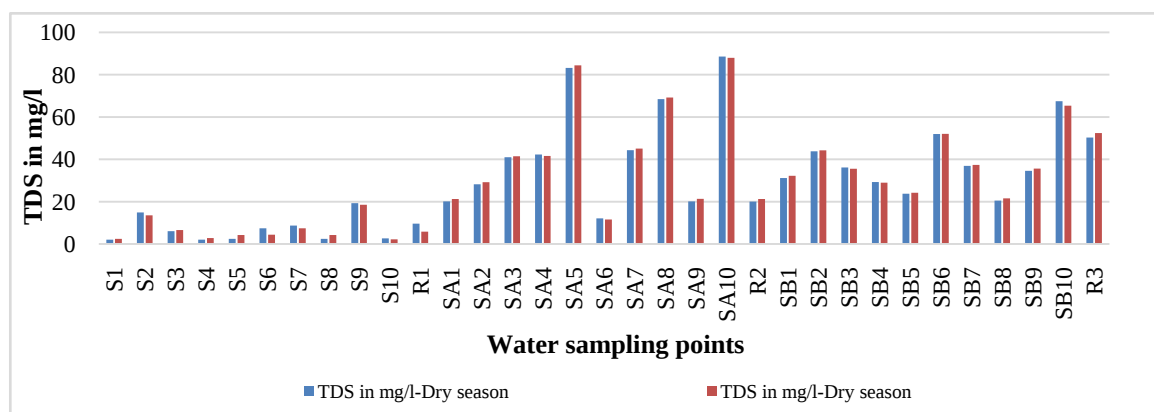


Figure 8. Mean TDS values for the Agro-ecological zones

3.1.7. Total Dissolved Solids (TDS)

The observed values of TDS in the River Malaget Sub-catchment ranged from 2.02 mg/l to 88.60 mg/l in the dry season and from 6.02 mg/l to 92.03 mg/l in the wet season. This indicates a very slight variation in the concentration of TDS between the two seasons. The TDS values for both the springs and streamflow were within the limits of < 1200 mg/l and < 1000 mg/l for drinking water as recommended by both [21] and [22].

3.1.8. Turbidity

The observed values of turbidity in the River Malaget Sub Catchment ranged from 0.82 NTU to 55.70 NTU in the dry season and from 24.01 N.T.U to 56.2 N.T.U in the wet season. There is generally higher turbidity levels in

the wet season compared to the dry season, which can be attributed to increased pollution due to run-off. The overall mean value for turbidity in the sub-catchment was 15.23 NTU. The turbidity values for both the springs and streamflow were within the limits of < 5 NTU for drinking water as recommended by both [21] and [22].

3.1.9. E.coli

The observed values of *E.coli* in the River Malaget Sub-catchment ranged from 0 CFU / 100 ml to 51 CFU / 100 ml in the dry season and 0 CFU / 100 ml to 82 CFU / 100 ml in the wet season. There is a very slight difference in *E.coli* pollution between the two seasons.

The *E.coli* values for most of the sampling points were within the limits of 0 CFU / 100 ml of water as

recommended by both [21] and [22] for drinking water. This means that *E.coli* should not be present in any sample of drinking water measured per 100 ml. This is except for 9 sampling points in the dry season and 14 sampling points in the wet season, which recorded *E.coli* pollution and all of which are spring sources. Run off incidences in the wet season could be responsible for the increase in sampling points polluted by *E.coli*. During a rainstorm human and animal waste are carried and end up in the spring pools thereby introducing *E.coli* pollution in them.

3.1.10. Biological Oxygen Demand (BOD)

The observed values of BOD in the River Malaget Sub Catchment ranged from 0 mg/l to 5.13 mg/l in the dry

season and from 0 mg/l to 4.36 mg/l in the wet season. The variation in the concentration of BOD between the two seasons is very minimal.

The BOD values for both the springs and streamflow were within the limits of 3 mg/l for drinking water as recommended by [22]. BOD is an indicator of oxygen depletion in drinking water, as it is a measure of the amount of oxygen required by micro-organisms such as bacteria to breakdown organic matter in water. Thus, a high BOD is indicative of high levels of organic matter usually originating from waste water discharges. BOD of safe drinking water should be zero, which means that there is no organic matter content and thus no oxygen is required.

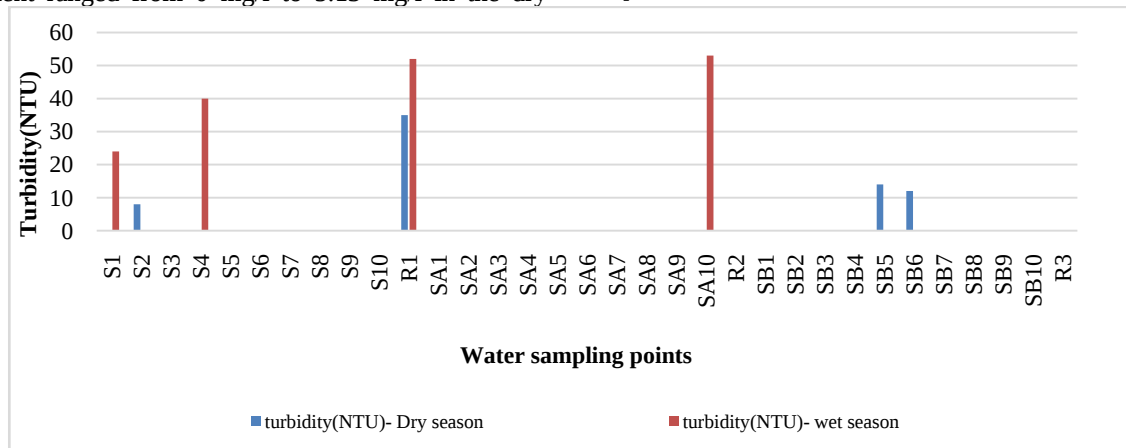


Figure 9. Mean turbidity values for the Agro-ecological zones

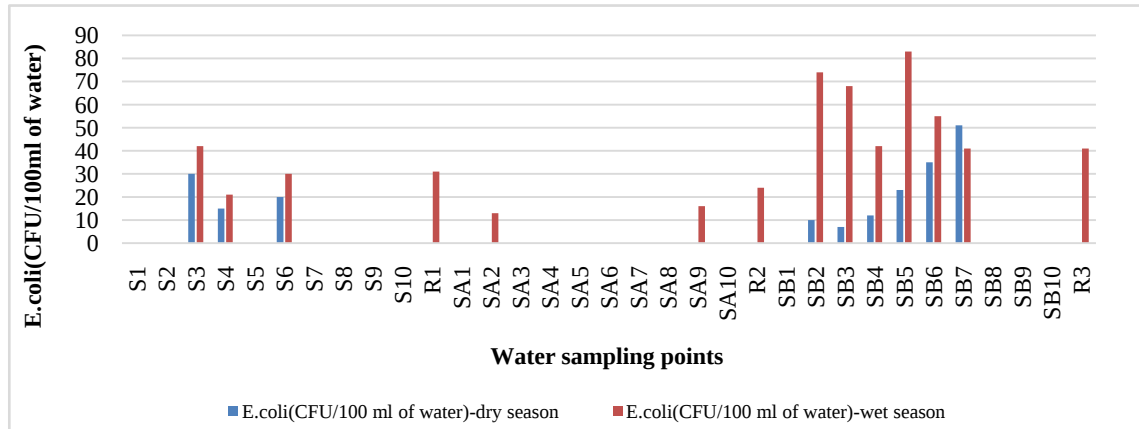


Figure 10. Mean *E.coli* values for the Agro-ecological zones

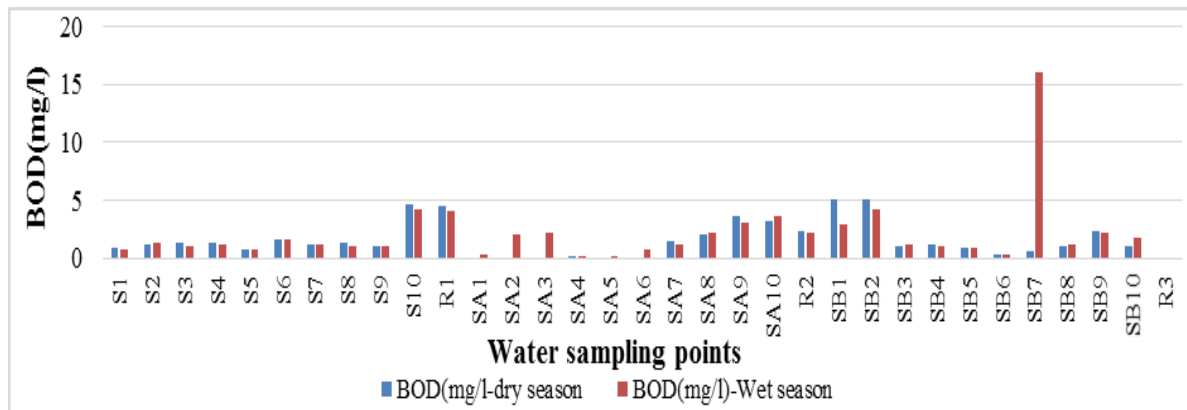


Figure 11. Mean BOD of the 3 Agro-ecological zones

3.1.11. DO

The observed values of DO in the River Malaget Sub Catchment ranged from 2.49 mg/l to 8.43 mg/l. The overall mean value for DO in the sub-catchment was 5.14 mg/l. There is no guideline value set for DO by either [21] or [22]. DO is an indicator of oxygen dissolved in drinking water which is largely a function of the water temperature.

3.1.12. Temperature

The observed values for water temperature in the River Malaget Sub Catchment ranged from 16.50°C to 24.20°C in the dry season and from 15°C to 23.1°C in the wet season. The overall mean temperature in the sub-catchment was 18.98 °C. Most of the sampling points recorded temperatures below 20 °C except for a few which

were within the limits of 20 - 35 °C for drinking water as recommended by both [21] and [22]. The possible explanation for temperatures below the lower limit of 20 °C is that these sampling points are springs. Usually springs are sheltered from direct sunshine by the vegetation growing around or nearby, hence the cool temperatures.

It is necessary that the temperature of drinking water is determined, as it is a crucial physical characteristic to the chemical properties of water. Temperature affects the chemical and biological reactions in water as it influences the dissolution of oxygen and the decomposition of organic matter. The higher the temperature the lower the DO levels in water, the higher the toxicity of ammonia, the more the micro-organism activity and the higher the acidity of water

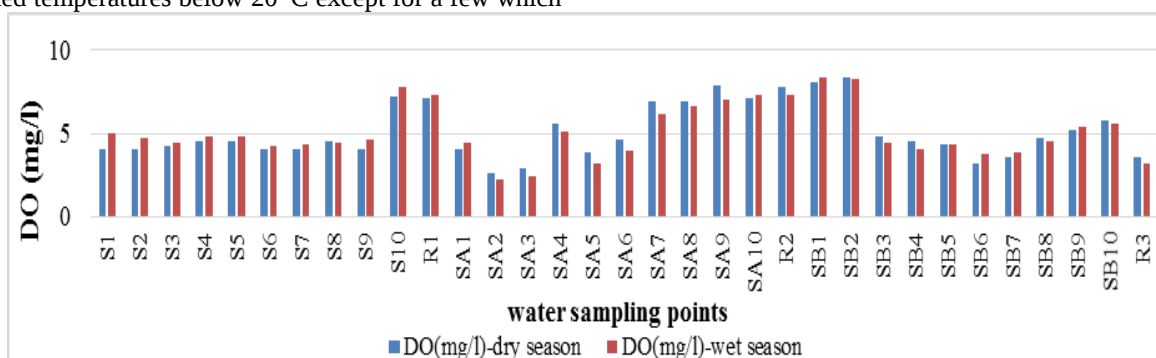


Figure 12. Mean DO of the Agro-ecological zones

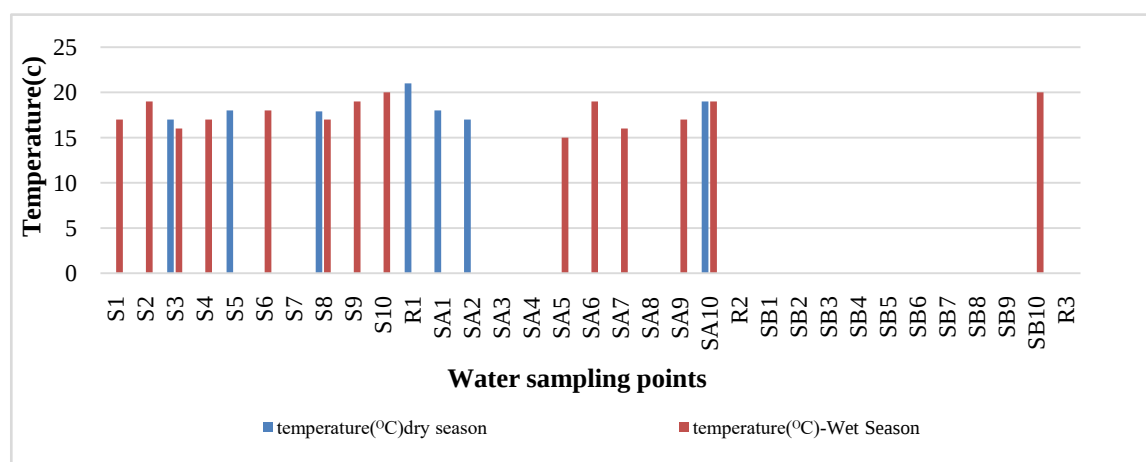


Figure 13. Mean temperature of the Agro-ecological zones

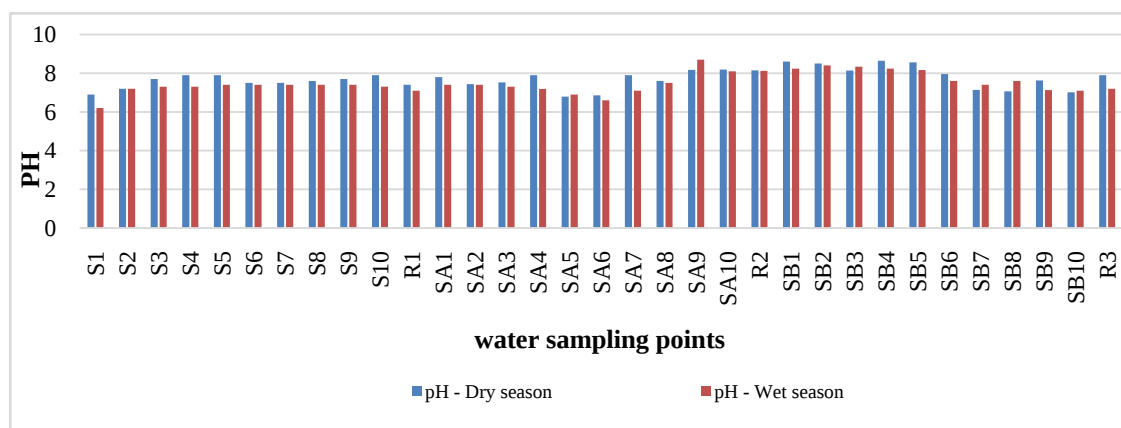


Figure 14. Mean pH of the Agro-ecological zones

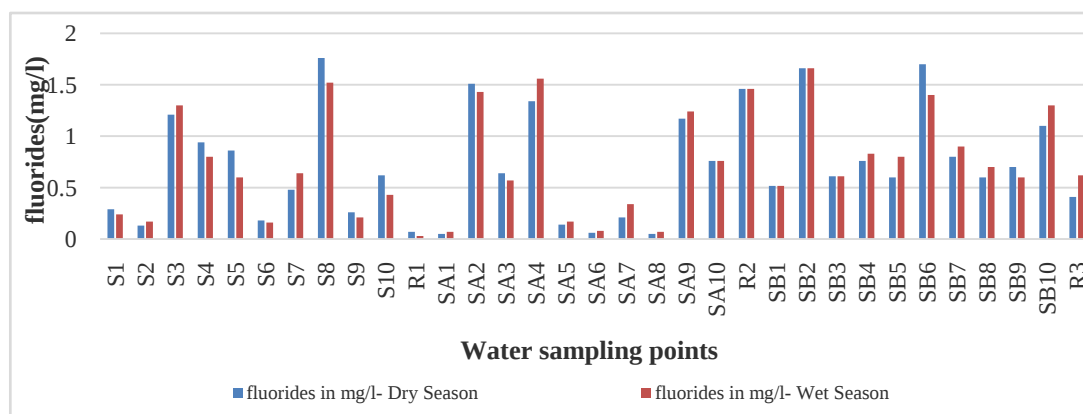


Figure 15. Mean fluorides of the Agro-ecological zones

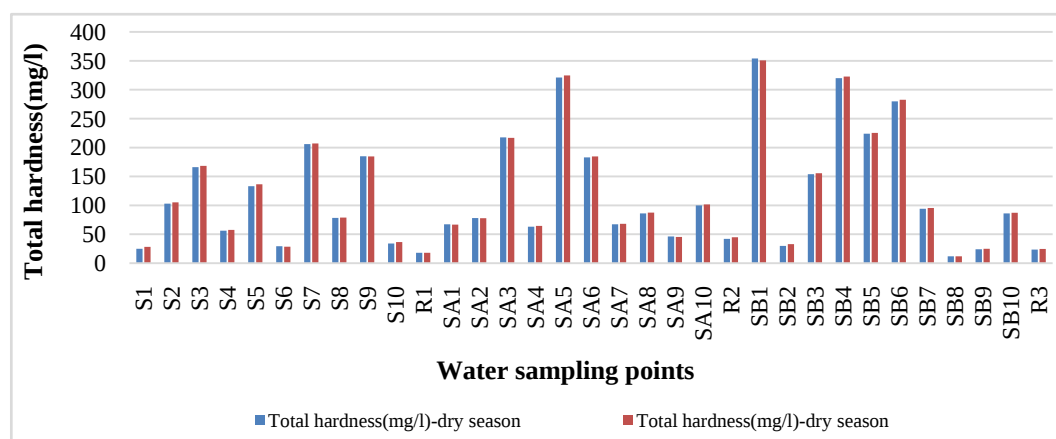


Figure 16. Mean Total Hardness values for the 3 Agro-ecological zones

3.1.13. pH

The observed values for pH in the River Malaget Sub Catchment ranged from 6.79 to 8.64 in the dry season and from 7.23 to 8.89 in the wet season. This indicates a very slight variation in pH levels between the two seasons.

The pH values for both the springs and streamflow were within the limits of 6.5 - 9.2 and 6.5 - 8.5 for drinking water as recommended by both [21] and [22] respectively; in both seasons. Generally, pH levels have no direct or immediate effect on consumers.

3.1.14. Fluorides

The observed values for fluorides in the River Malaget Sub Catchment ranged from 0.05 mg/l and 1.76 mg/l in the dry season and from 0.1 mg/l to 1.71 mg/l in the wet season. The fluoride values for both the springs and streamflow were within the limits of 1.5 mg/l for drinking water as recommended by both [21] and [22] with the exception of a few. These are four spring sites in the dry season and 5 spring sites in the wet season.

Excessive concentration of fluoride above 1.5 mg/l is associated with dental fluorosis or the browning of the teeth enamel. This study area, being in the Rift valley region which is known to have high fluoride levels in its geology, is expected to have some of its springs containing high levels of the same ions. This is because springs originate from underground and therefore the spring water interacts with the geology before being discharged. There is also not much seasonal variation in the levels of fluorides because these ions originate from

the underground and therefore the surface processes may not have much effect on its concentration.

3.1.15. Total Hardness (TH)

The observed values for Total Hardness in the River Malaget Sub Catchment ranged from 12 mg/l to 354.07 mg/l in the dry season and 13.4 mg/l to 325.4 mg/l in the wet season. The overall mean value for Total hardness in the sub-catchment was 118.39 mg/l. The Total hardness values for both the springs and streamflow were within the limits of < 500 mg/l for drinking water as recommended by both [21] and [22].

3.2. Mean Differences for Water Quality Parameters

Principal component analysis (PCA) and factor analysis using varimax rotation was used to reduce the 15 water quality parameters measured to only 9 that indicate nutrient and micro-organic pollution. This was necessary because the number of samples per group (N), which in this case was 11, should be greater than the number of dependent variables, which in this case were 15. These 9 parameters were then subjected to further analysis using Multivariate Analysis of Variance (MANOVA).

Factor analysis was conducted and principal component analysis (PCA) was used as the extraction method. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = .447 and all KMO values for individual items were < .5, which is the acceptable limit. Bartlett's test of sphericity χ^2 (66) =

171.425, $p < .001$, indicated that correlations between items were sufficiently large for PCA.

An initial analysis was run to obtain eigenvalues for each component in the data. Five components had eigenvalues over Kaiser's criterion of 1 and in combination explained 77.46% of the variance. Given the convergence of the scree plot and Kaiser's criterion on five components, this is the number of components that were retained in the final analysis.

Table 1. Rotated Component Matrix

Parameters	Component				
	1	2	3	4	5
BOD in mg/L	.925				
DO in mg/L	.925				
pH	.678		.537		
turbidity in N.T.U	.658			.534	
ammonia		.896			
phosphates in mg/L		.862			
conductivity in $\mu\text{S/cm}$			.830		
<i>E.coli</i> in C.F.U./100 mL			.706		
nitrites				.773	
TSS in mg/L				.699	
nitrites in mg/L					.892
temperature in $^{\circ}\text{C}$		.542			-.680

Table 1 shows the factor loadings after orthogonal (varimax) rotation. The items that cluster on the same components suggest that factor 1 represents measures of oxygen levels (BOD, DO); factor 2 represents measures of pollution from nutrients (ammonia, phosphates), that are sensitive to temperature levels ; factor 3 represents measures of pollutants that are sensitive to pH levels (electrical conductivity and *E.coli*) ; factor 4 represents measures of pollutants in suspension which are sensitive to turbidity levels (TSS and nitrites) and factor 5 represents pollutants from nutrients which are sensitive to temperature levels (nitrate).

MANOVA was used to compare the means of the three agro-ecological zones, i.e., Tea-Dairy Zone, Wheat/Maize/Barley Zone, and Marginal Coffee Zone. Using Pillai's Trace, there was significant variability in the distribution of water quality parameters in relation to land use as the means of the three agro-ecological zones were significantly different, $V = 0.75$, $F(9, 23) = 7.70$, $p < .05$. This is illustrated by Table 2. Pillai's Trace is the most robust of the four multivariate tests when the group sizes are equal and when comparing the means of several dependent variables per group. In addition, it is also the safest test and the most robust to violations of MANOVA assumptions.

Table 2. Summary of MANOVA Tests

Test	Value	F	Hypothesis df	Error df	Sig.
Pillai's Trace	.751	7.696	9.000	23.000	.000
Wilks' Lambda	.249	7.696	9.000	23.000	.000
Hottelling's Trace	3.012	7.696	9.000	23.000	.000
Roy's Largest Root	3.012	7.696	9.000	23.000	.000

The univariate ANOVAs on each of the dependent variables revealed significant effect on electrical conductivity, $F(1, 31) = 329402.91$, $p > .05$; phosphates,

$F(1, 31) = 0.001$, $p > .05$; and ammonia, $F(1, 31) = 0.006$, $p > .05$. Table 3 shows the results for the univariate ANOVA tests that followed-up the main MANOVA analysis.

Table 3. Test of Between Subjects Effects

Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Conductivity in $\mu\text{S/cm}$	329402.91	1	329402.91	24.174	.000
DO in mg/L	.208	1	.208	.086	.771
TSS in mg/L	.359	1	.359	.553	.463
<i>E.coli</i> in C.F.U./100 mL	242.227	1	242.227	1.604	.215
BOD in mg/L	.016	1	.016	.005	.946
nitrites in mg/L	15.376	1	15.376	.217	.645
phosphates in mg/L	.001	1	.001	4.968	.033
Nitrites in mg/L	8.542E-005	1	8.542E-005	3.704	.063
Ammonia in mg/L	.006	1	.006	8.865	.006

The MANOVA was also followed up with discriminant function analysis, which revealed two discriminant functions. The first explained 79.5% of the variance, canonical $R^2 = .52$, whereas the second explained only 20.5%, canonical $R^2 = .22$. In combination these discriminant functions significantly differentiated the treatment groups, $\lambda = 0.378$, $\chi^2(4) = 28.673$, $p < .05$, and even removing the first function indicated that the second function still significantly differentiate the treatment groups, $\lambda = 0.784$, $\chi^2(1) = 7.187$, $p < .05$.

The correlations between outcomes and the discriminant functions revealed that electrical conductivity loaded very highly onto the first function ($r = .942$) and lowly on the second function ($r = .336$); turbidity loaded more highly on the first function ($r = -.091$) than the second function ($r = -.027$); nitrites loaded very highly onto the second function ($r = .924$) and lowly on the first function ($r = -.382$); and temperature loaded very highly onto the second function ($r = -.237$) and lowly on the first function ($r = .050$). The discriminant function plot showed that the second function discriminated the Tea-Dairy Zone from the Wheat/Maize/Barley Zone, and the first function differentiated the Marginal Coffee Zone from the two zones, that is, Tea-Dairy Zone from the Wheat/Maize/Barley Zone.

4. Conclusion

The null hypothesis - there is no significant variability in the distribution of water quality parameters in relation to land use - was tested using MANOVA. The means of each parameter was compared amongst the three agro-ecological zones. The univariate ANOVAs on each of the dependent variables revealed significant effect on temperature, nitrites, electrical conductivity and turbidity. Hence, it can be concluded that indeed land use has an impact on the water quality of the study area, considering the spatial distribution of temperature, nitrites, electrical conductivity and turbidity.

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Statement of Competing Interests

The authors have no competing interests

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