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Seasonal Variation of Major Nutrients and Selected Physicochemical Parameters in Soil from Small Scale Tea Farms Along Sulal River, Bureti Sub County, Kericho County, Kenya

Abong'o. D.A , Cherotich.S., Onyatta. J.O

Faculty of Science & Technology, Department of Chemistry, University of Nairobi, Kenya

P.O BOX 30197-00100, Nairobi, Kenya

Corresponding author: dabongo@uonbi.ac.ke

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ABSTRACT

A study was conducted to evaluate seasonal variations of major nutrients and selected physicochemical parameters in soils. The soil samples were collected from small scale tea farms adjusted to Sulal River in Kenya before and after the application of nitrogen, phosphorous, potassium (NPK) fertilizer in order to ascertain the farmer's role in controlling the movement of chemical nutrients into the river. Ten soil samples were collected from selected ten different tea farms and analyzed for pH, percentage moisture content (MC), electrical conductivity (EC), nitrate-nitrogen (NO_3-N) and phosphorous (PO_3-P) were analysed calorimetrically using Salicylic acid and Olsen methods respectively while potassium by flame photometer. Standard methods, IBM SPSS 20 was used for data analysis. The results during dry season revealed that the range of pH was 4.07±0.03 - 4.98±0.08, MC was 12.58±0.52 - 21.76±0.52 %, EC was 85±7.85- 245±6.50 µS/cm, NO_3-N was 0.14±0.03 - 0.87±0.01mg/L, PO_3-P was 0.06±0.03 - 0.32±0.04mg/L and K was 0.98±0.36- 2.05±0.28 mg/L while during rainy season, the range of pH was 4.18±0.03-4.80±0.12, MC was 30.92±0.56- 37.36±0.45 %, EC was 216±3.72- 289±7.25µS/cm, NO_3-N was 0.33±0.04- 0.90±0.07mg/L, PO_3-P was 0.08±0.07– 0.68±0.04mg/L and K was 1.65±0.35-3.48±0.15 mg/L Seasonal variation revealed significant differences in all parameters except NO_3-N and PO_3-P. The correlation study indicated that moisture content was significantly correlated to electrical conductivity, PO_3-P and K while electrical conductivity and PO_3-P were both significantly correlated to K. The soils in both seasons had low major nutrients contents. Stringent legislation on management of soils along the rivers is recommended.
Keyword: Soil, Tea farms, nutrients, physicochemical parameters, assessment levels

I. Introduction

Tea production is the main agricultural activity in Kericho County and the largest producer in Kenya [1]. The tea small farm holders are concentrated in Bureti Sub-County while the tea estates sub-sectors are spread in Kipkelion, Belgut and Ainamoi East Sub-Counties [2]. In Bureti Sub-County, tea is grown in rain fed sloping areas at an altitude of 1000-2000 m. The nutritional status of the tea plant and that of the soil largely depends on the amount of fertilizer applied [3]. Use of fertilizers in tea cultivation is therefore an important field management practice meant for improving crop yields and influencing quality of the final product. The commonly used top dressing fertilizer in Kenya by small scale tea farmers is the inorganic blend of nitrogen, phosphorous and nitrogen (NPK) in the ratio of 26:5:5 supplied by the Kenya Tea Development Authority[4]. Tea requires moderate to high nutrient levels in soil because low levels of nutrients in tea would lower the quality and quantity of tea[5]. It is well known that excess nutrients from application of fertilizers can affect the physicochemical parameters of soil and pollute the surrounding environment [6]. The levels of nutrients and physicochemical parameters of soil such as pH, electrical conductivity and moisture content are also influenced by factors such as vegetation cover, the slope of the farm, land use, fertilizer application pattern and rainfall pattern[7]. Soil pH affects nutrients availability; when the pH is out of range, plants cannot absorb nutrients even when there is plenty in the soil[8]. Electrical conductivity of soil is an indication of health status of soil; healthy soils have optimal electrical conductivity (EC) levels that range from 110-570 (mS/m). Too low electrical conductivity level is an indication of low nutrients available for the plant, while too high electrical conductivity level show that there are excess available nutrients in soil[9]. Soil moisture affects the availability and transformation of nutrients in soil and the biological activities in soil[10]. Studies on water quality around tea producing regions in Kenya show that fertilizer runoff from tea farms increases the amount of nutrients in water bodies[11]. In the soil, nitrogen is converted by bacteria present in soil to nitrate (NO_3^-), a form which is the most desirable by plants[12]. However, this form is very loosely bound to soil hence, easily washed by rain into surface water or leached into ground water [13]. Phosphates applied to agricultural farms as fertilizers and is not utilized by plants can be in the runoff during rainy seasons into the surface water or migrate vertically into groundwater system[14]. The availability of phosphorus and nitrogen in rivers, promotes eutrophication [15]. The Sulal River in Kenya is also a victim of nutrient pollution as it passes through small scale tea farms[16]. The river supplies water for domestic purposes and livestock farming. The main activity along the river is tea farming and the application of fertilizers by the farmers may be a threat to the environment especially soil and water quality in surrounding catchment[16]. This study aimed to determine the levels of major nutrients and physicochemical parameters in the soils for agricultural activities and environmental contents, it also determined the effects of dry and wet seasons on the levels of the analytes and proposed some necessary policies on soil management.

II. Methods and Materials

The study area was along Sulal River, located in Bureti Sub County, Kericho County and lies between Latitude 0°39'14"S and Longitude 35°10'41"E (Figure 1). The most important economic activity in Sulal River catchment area is tea farming. Tea leaves produced area are taken to Kapkatet Tea Factory which is managed by Kenya Tea Development Authority (KTDA). KTDA buys fertilizers in bulk and supplies to the all the farmers on loan basis [17] to be applied on the onset of the short rains, between October and December. During the dry season, usually January and February, farmers prepare their tea farms for fertilizer application by weeding. The climate is moderately humid with average temperature of 18°C annually. The annual rainfall has a mean of 1800 mm and is bi-modal where long rains occur from early March to June and short rains occur from October to December[2]. The county has experienced adequate rainfall for a long time but for the last three decades there has been gradual changes due to emerging changes in the weather patterns[18]. In 2019 and 2020, rainfall was erratic throughout the years; long rainy season occurred in July to December, excess precipitation that resulted in flash floods destroying crops and polluting rivers, and prolonged dry season characterized with decreasing moisture contents that negatively affected tea and other agricultural crops. In the year 2019, the driest season began from January to April while heavy rains began from July 2019 through March 2020[18].

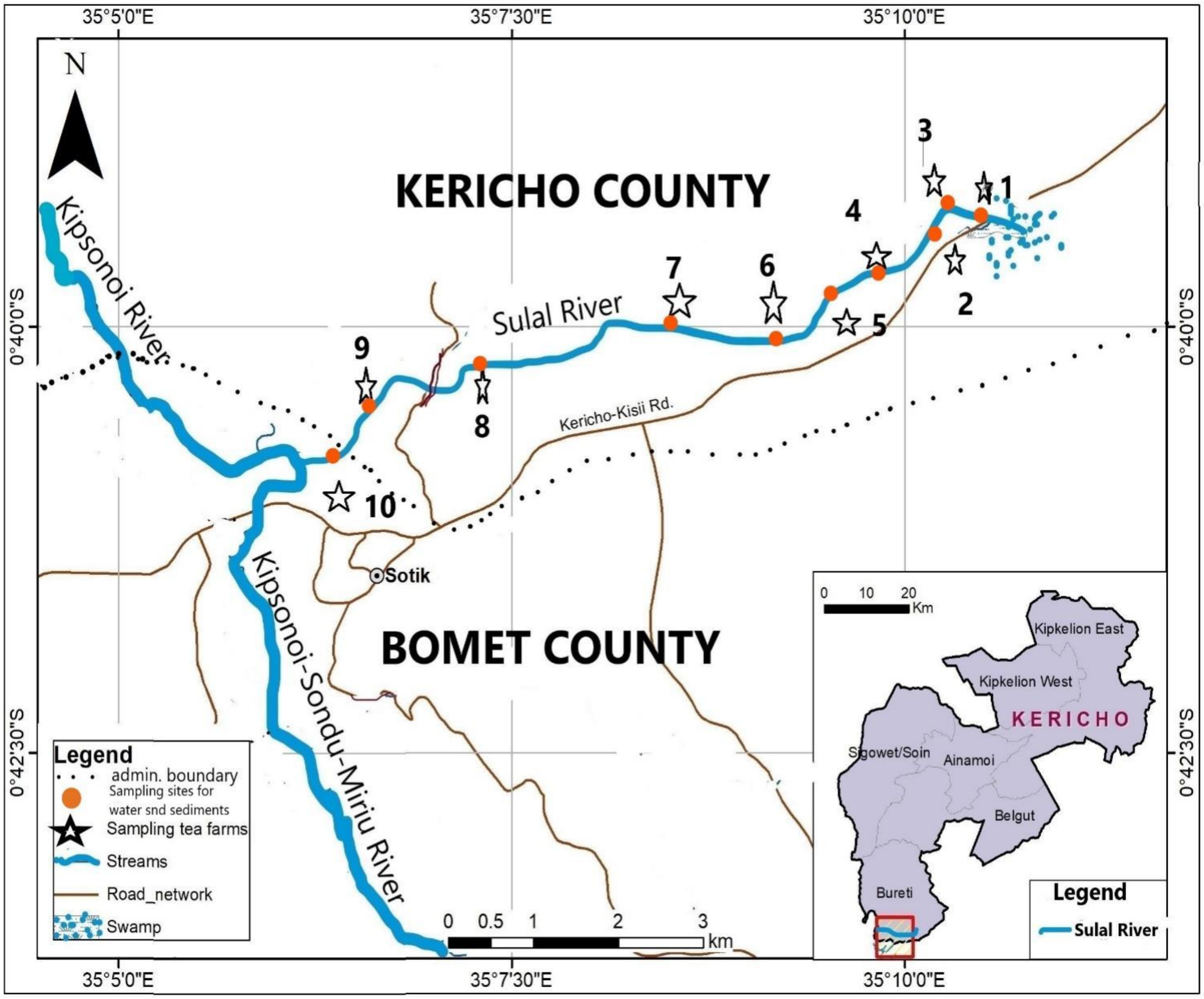

Figure 1: Map of Sulal River showing sampling sites

[Source[16]]

2.1. Chemicals and Reagents

Sodium thiosulfate (98.0 %), starch solution, alkali-iodide-azide, Manganese sulfate (98.5 %), concentrated sulfuric acid (97 %), distilled water, K_2SO_4 (99.0 %), NaOH (98.0 %), salicylic acid (99.0 %), $NaHCO_3$ (98.0 %), HCl (99.0 %), Ammonium Molybdate (99.9 %), antimony potassium tartrate (98.0 %), ascorbic acid (99 %), KNO_3 (99.9 %), KH_2PO_4, (99.9 %), and KCL (99.0 %). The chemical and reagents were manufactured by Sigma-Aldrich Company, USA.

2.2. Instruments and apparatus

UV-VIS Spectrophotometer (MR Spectronic 1001 PLUS), flame photometer (EEL 100), analytical balance (C054-E032Q Shimadzu), pH-EC-TDS meter (HANNA 9812), mechanical orbital shaker, extraction bottle with stopper, laboratory glassware and sampling bottles and bags were used

2.3. Sampling sites selection

The coordinates as well as location and activities at the sampling sites along Sulal River are shown in Table 1.

Table 1. Location coordinates and description of the soil sampling sites along Sulal River

Local name	Sites	Latitude	Longitude	Altitude (m)	Description
Kapkatet	1	0°39'14"S	35°10'41"E	1887	The bushes in this farm are all mature tea. Sloppy.
	2	0°39'23"S	35°10'39"E	1872	Consist of mature tea. Very sloppy.
	3	0°39'22"S	35°10'26"E	1894	Consist of pruned mature tea. The soil surface was mostly covered.
	4	0°39'26"S	35°09'59"E	1882	Mature tea. The farm is sloppy
Chebongi	5	0°39'31"S	35°09'28"E	1845	Mature pruned tea. It touches the river. Flat.
	6	0°39'40"S	35°09'11"E	1880	Young tea bushes. No vegetation covers. Flat, but the farm above it is very sloppy.
	7	0°39'53"S	35°07'13"E	1799	Mature tea bushes. Levelled land
Sertwet	8	0°39'54"S	35°07'13"E	1796	Mature tea bushes. Sloppy farm and there are a flat field below it
	9	0°40'19"S	35°06'57"E	1803	Mature tea bushes. Sloppy
	10	0°40'44"S	35°06'15"E	1766	Mature tea bushes. sloppy

2.4. Samples collection

Soil samples from the selected 10 farms (Table 1) were collected following procedures[19]. 10 spots from each farm were selected for one composite sample. Soil was dug from the depth of 0-10 cm, taken using a spade and mixed. All samples from one farm were mixed to form a composite sample. Triplicates, 1000g each, were taken from each farm, labelled packed in a plastic container with a lid, labelled and kept in polyethene cooler boxes awaiting transportation to the University of Nairobi Laboratory. In the laboratory each sample was analyzed for pH, electrical conductivity (EC), percentage moisture content (MC) and major chemical nutrients (NPK).

2.5. Preparation of samples for analysis

In the laboratory, soil samples were dried using a memmert oven at 105°C for 24 hours. External objects were removed, and a roller was used to break down the large masses of the soil particles. Samples were then sieved using a 2.0 mm mesh and kept for subsequent analysis in a refrigerator using labeled plastic bags.

2.6. Sample analysis

Soil samples were analyzed for pH, moisture content (MC), electrical conductivity (EC), nitrogen (N), phosphorous (P) and potassium (K). The pH and EC were determined using HANNA 9812 combined meter, while moisture contents were determined by weighing samples before and after oven-drying at 105°C for 15 hours. Nitrogen, as nitrate-nitrogen (NO_3–N) and phosphorous, as phosphate-phosphorous (PO_4-P) were analyzed calorimetrically using Salicylic acid and Olsen methods respectively while potassium was determined using flame photometer.

2.7. Data analysis

Statistical program for social scientists (IBM SPSS Version 20) was used to obtain the mean and standard deviation, paired sample t test for comparison of the means between seasons and Bivariate Pearson's correlation between any two parameters. Differences were regarded to be significant at 95% confidence limit.

III. Results and Discussions

3.1. Physicochemical parameters and nutrients levels in soils in dry and rainy seasons

The results of the physicochemical parameters and nutrients levels in the soils samples in dry and rainy seasons are shown in Table 2.

The pH of soil samples during dry season ranged from 4.07±0.03 to 4.98±0.08 and in rainy, the values were from 4.18±0.03 to 4.80±0.12 (Table 2). The pH range in both seasons indicates moderate acidity. The pH levels fell within the range of tea soils[20] pH (4.0-5.0). A previous study carried out in a similar environment demonstrated the same trend with the values of pH varying from 4.1 - 4.8 and 3.9 - 4.5 during the dry and rainy seasons respectively[21]. According to previous study, the different levels of nitrates and phosphates observed in this study could have attributed to the different levels of pH in each farm[21]. Soil pH affects nutrient availability especially phosphorous and potassium; phosphorous is unavailable to plants at pH of <5.5 and >7 while potassium is replaced by more oxidizing cations such as Al^+, H^+ and Mn^+ in low soil pH[22].

The soil moisture content ranged from 12.58±0.53 % to 21.76±0.52 %. Similarly, soil moisture content during rainy season ranged from 30.13±0.48 % to 37.36±0.45%. Moisture content affects the availability of nutrients in soil because the activity of soil microorganisms which play an important role in breaking down organic matter and mineralization of organic phosphorous and nitrates to their respective inorganic form is favored in moist soils[23]. Reduction in soil moisture content greatly affects absorption of soil nutrients and limits the growth of tea bushes, thus affecting crop yield and accumulation of tea secondary metabolites[24].

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Electrical Conductivity (EC) of soil ranged from 85±7.85 to 245±6.50 µS/cm and 216±3.72 to 289±7.29 µS/cm during dry and rainy seasons respectively (Table 2). These values indicated a relatively low salinity due to significant presence of inorganic ions in the soil[21]. The level of EC obtained in this study is similar to that reported in tea farms in Kisii and also attributed different values of electrical conductivity in soil to different levels of soil nutrients[25]

Table 2: Soil physicochemical parameters and nutrients levels in dry and wet seasons

	Dry season					
Parameter/ Site	pH	MC (%)	EC (µS /cm)	$N0_3$-N (mg/kg)	PO_3-P (mg/kg)	K (mg/kg)
1	4.80±0.12	14.78±0.37	150±5.29	0.56±0.06	0.10±0.04	1.12±0.15
2	4.57±0.08	14.93±0.20	190±5.24	0.60±0.02	0.15±0.03	1.29±0.28
3	4.45±0.02	18.46±0.39	187±3.89	0.87±0.01	0.22±0.08	1.14±0.14
4	4.80±0.01	16.96±0.26	182±4.20	0.51±0.06	0.17±0.03	1.09±0.19
5	4.62±0.05	21.76±0.52	245±6.50	0.24±0.04	0.32±0.04	2.05±0.28
6	4.07±0.03	14.17±0.36	133±3.87	0.67±0.02	0.09±0.08	1.09±0.29
7	4.55±0.10	16.87±038	175±5.30	0.79±0.02	0.18±0.02	1.11±0.10
8	4.86±0.01	14.71±0.18	140±5.50	0.84±0.08	0.08±0.05	1.04±0.27
9	4.71±0.02	21.63±0.41	220±5.25	0.14±0.03	0.23±0.04	1.24±0.18
10	4.98±0.08	12.58±0.53	85±7.85	0.58±0.03	0.06±0.03	0.98±0.36
M± SD, n=10	4.64±0.26	20.91±3.11	187±45.79	0.68±0.20	0.14±0.08	1.22±0.31
	Rainy season					
1	4.38±0.06	30.92±0.56	242±4.20	0.43±0.04	0.38±0.07	2.56±0.11
2	4.47±0.01	33.95±0.35	250±6.01	0.54±0.07	0.47±0.04	3.39±0.21
3	4.32±0.06	37.36±0.45	289±7.29	0.79±0.03	0.68±0.04	3.48±0.15
4	4.42±0.09	32.82±0.34	248±4.85	0.63±0.03	0.31±0.06	2.06±0.22
5	4.25±0.08	32.12±0.20	221±8.47	0.90±0.07	0.12±0.07	1.65±0.35
6	4.18±0.03	36.45±0.41	259±4.98	0.37±0.09	0.42±0.08	2.87±0.16
7	4.45±0.01	35.56±0.37	260±3.45	0.61±0.05	0.27±0.03	1.85±0.20
8	4.80±0.12	37.12±0.29	287±6.71	0.38±0.08	0.56±0.06	3.44±0.14
9	4.24±0.09	30.13±0.48	216±3.72	0.81±0.09	0.08±0.07	2.02±0.31
10	4.58±0.02	34.40±0,34	253±4.80	0.33±0.04	0.46±0.07	2.98±0.25
M ±SD, N=10	4.41±0.18	36.38±2.20	253±23.76	0.58±0.20	0.38±0.17	2.63±0.70

Nitrogen levels ranged from 0.14±0.03 - 0.87±0.01 mg/kg and 0.33±0.04 - 0.90±0.07 mg/kg in the dry and rainy seasons respectively (Table 2). The nitrogen levels in soil from all samples in both seasons were low according [4]. This explains the regular application of fertilizers by the farmers. The low nitrogen level in soil is possibly due to immediate absorption of nitrogen by tea plants after fertilizer application[26] or loss through surface runoff, volatilization, denitrification, or leaching[11]. Similar observation was made in soils from Kericho and this attributed low levels of nitrogen in soil to leaching[27].

The phosphorous levels ranged from 0.06 ± 0.03 to 0.32 ±0.04 mg/kg during dry season and ranged from 0.08±0.07 to 0.68±0.04 mg/kg. (Table 2). The mean concentrations for both seasons were lower than the recommended level of 5 mg/kg for tea[4] and this is the reason for annual application of fertilizers. Low levels of phosphorous in soils is possibly because majority of phosphorous in soils is fixed, and hence, plant available phosphorous is scarcely available despite the abundance of both inorganic and organic phosphorous in soils [28]. Low phosphorous levels in soil from Muranga by Mucheru-Muna and her colleagues were also recorded and they attributed it to inadequate application of fertilizers by poor-resource farmers who consider fertilizer application a luxury, leading to poor crop performance[29].

Available potassium content during dry season ranged from 0.98 ±0.36 to 2.05 ±0.28 mg/kg. Similarly, in rainy season, a range of 1.65±0.35 to 3.48 ±0.15 mg/kg were recorded (Table 2). The lower than the recommended level of potassium (>78mg/kg) in both seasons is because potassium is loosely attached to the soil organic matter and it can directly be washed from the soil in rainy season[30]. The low potassium levels recorded in this study is similar to Ruto who concluded that the low levels of soil potassium in dry and rainy seasons following application of NPK fertilizers is attributed to low soil pH leading to replacement of potassium ions by more oxidizing[27] cations such as Al^{+}, H^{+} and Mn^{+}.

3.2. Seasonal variation of soil physicochemical parameters and nutrients levels

The effects of seasons on the levels of physicochemical parameters in soil samples are shown in Figures 2-7. The mean levels of each parameter in 10 sites (n=3) were compared in each season using t-test and recorded in Table 3.

Results in Figure 2 show that except Site 6, the pH levels of soil in other sites were slightly higher during dry than rainy season. Site 6 was a young tea bushes, no vegetation covers, flat, and the farm above it was very sloppy (Table 1). Therefore, pH was lower than these of the other sites because it had no vegetable cover, the H^{+} ions were washed away in the two seasons. However, the mean pH value was significantly lower in rainy than dry seasons (Table 2). Soil become acidic in rainy season because during such season, basic cations such as magnesium, calcium and potassium are leached from soil profile leaving behind more stable materials rich in Fe and Al oxides. The presence of these compounds makes soil acidic and generally devoid of nutrients[31]. Similar variation in the tea garden soil of Golaghat District, India was reported [32].

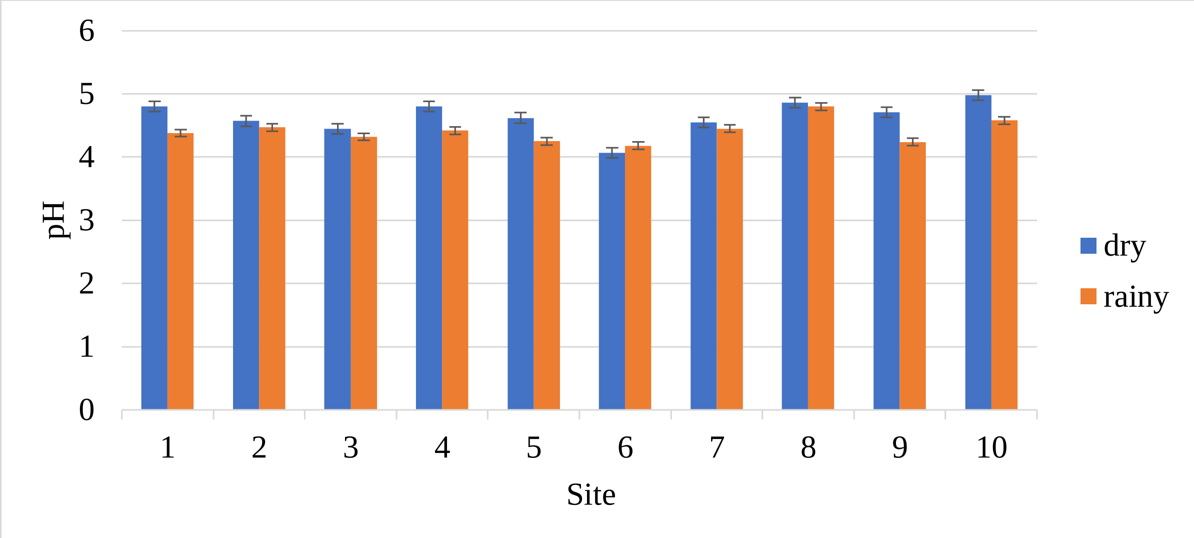

Figure 2. pH values

Moisture contents of all soil samples were higher during wet than dry season (Figure 3). The seasonal variation of moisture content differs significantly ($p<0.01$) (Table 3). The moisture contents were higher in Site 3 than the other sites in wet season. Site 3 consisted of pruned mature tea (Table 1), therefore soil surface was mostly covered.

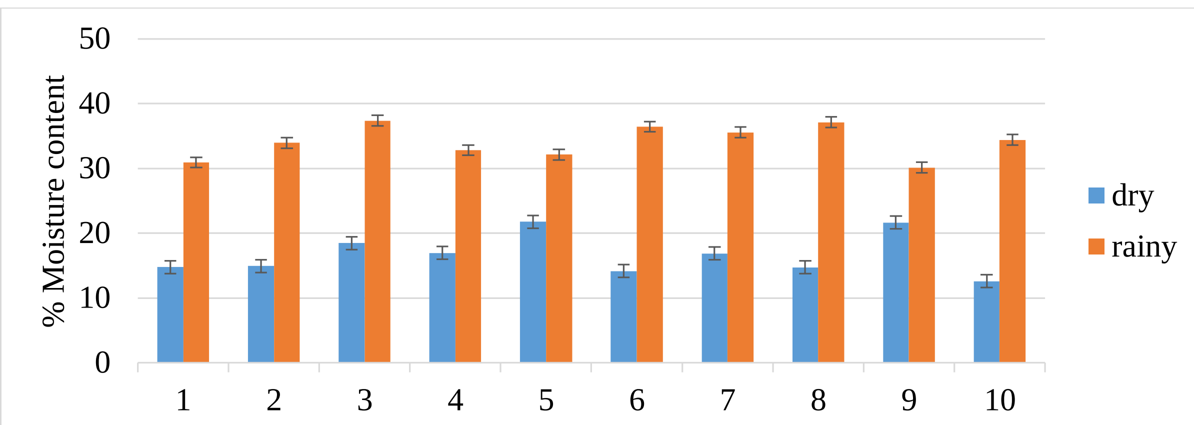

Figure 3. Moisture content

The electrical conductivities (EC) of all soil samples except from Sites 5 and 9 were higher in rainy than the dry seas, (Figure 4). Site 5 is mature pruned tea farm, flat and farm soil touched the water river, (Table 1) because of these the river water washes away the electrical chemicals ions from the soil in the wet season. Site 9 is a mature tea bushes, sloppy tea farm (Table 1), whose soil electrical chemical ions contents have been drained off in the wet reason. The seasonal variation (Table 3) showed significant difference (p=0.02). Higher EC during rainy season is attributed to application of fertilizers and also the fact that water helps to free up some ions in soil and hence increase the EC [9].

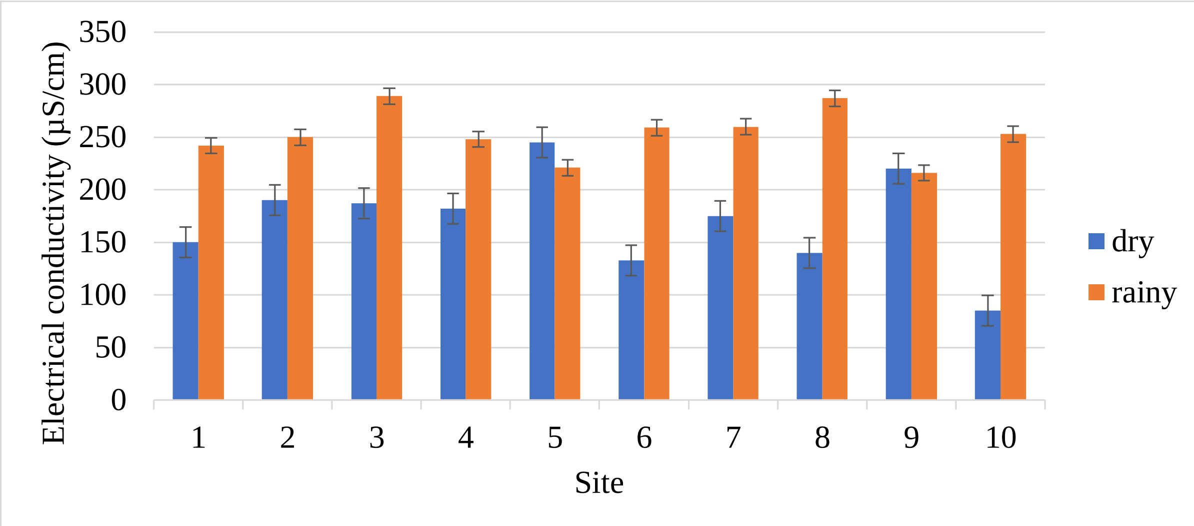

Figure 4. Electrical Conductivity of soil samples

Except for soil samples from Sites 4, 5 and 9, nitrogen levels were lower in rainy season than dry season (Figure 5). Their mean levels in dry and rainy seasons did not significantly differ (Table 3). The low level of nitrogen during rainy season is possibly because nitrates dissolve immediately after the onset of rainfall and are taken up by tea plant, leached or carried away by water run-off. During dry season, nitrates are usually built up through decomposition of proteins and nucleic acid from dropped tea leaves and other nitrogenous organic substances in soil releasing NH_3 which is converted to nitrates[33]. The seasonal variation of nitrate-nitrogen observed in this study agreed with the results [34]. The nitrate concentrations rose steadily according after the onset of the rains and decreased drastically as rain continued because the rains can carry nitrates flushed out by the initial rains[34].

Table 3. Paired sample T test for analytes and mean levels in soil in dry and wet seasons

Pairs		t	df	Sig. (2-tailed)
pH	dry - rainy	3.705	9	.005
MC	dry - rainy	-11.452	9	.000
EC	dry - rainy	-4.244	9	.002
$N0_3$-N	dry - rainy	.008	9	.994
PO_3-P	dry - rainy	-2.829	9	.020
K	dry - rainy	-5.030	9	.001

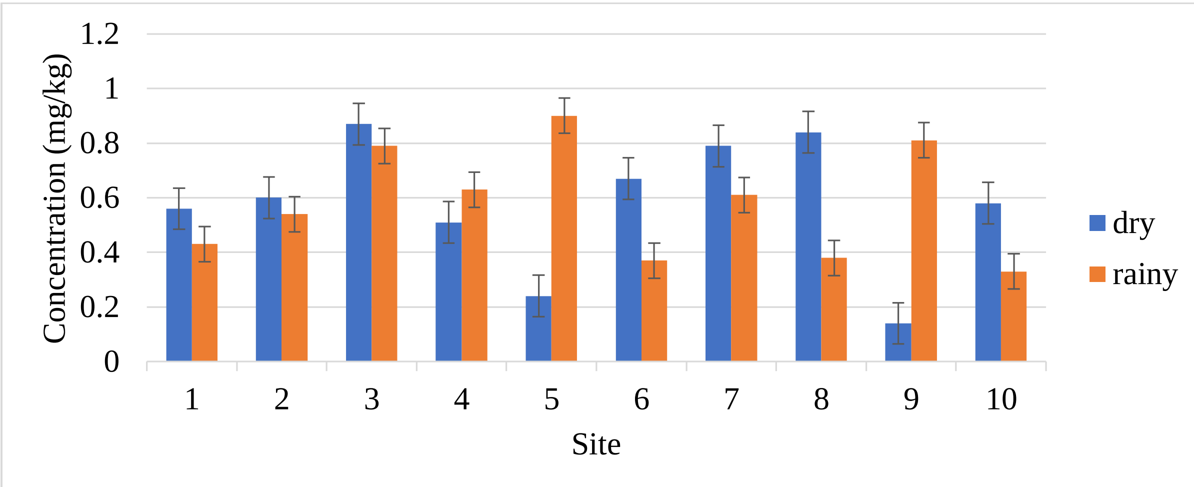

Figure 5. Nitrogen levels in soil samples

Phosphorous levels in soil samples except from sites 5 and 9 were higher in rainy season than in dry season (Figure 6), however their means did not vary significantly (Table 3). The higher level of phosphorous during rainy season is possibly due to the application of phosphorous-containing fertilizers during rainy season[36]. Similar variation was reported that tea soils in China contained high levels of phosphates after application of phosphorous-containing fertilizers, implying that phosphates cling tightly to soil particles [36].

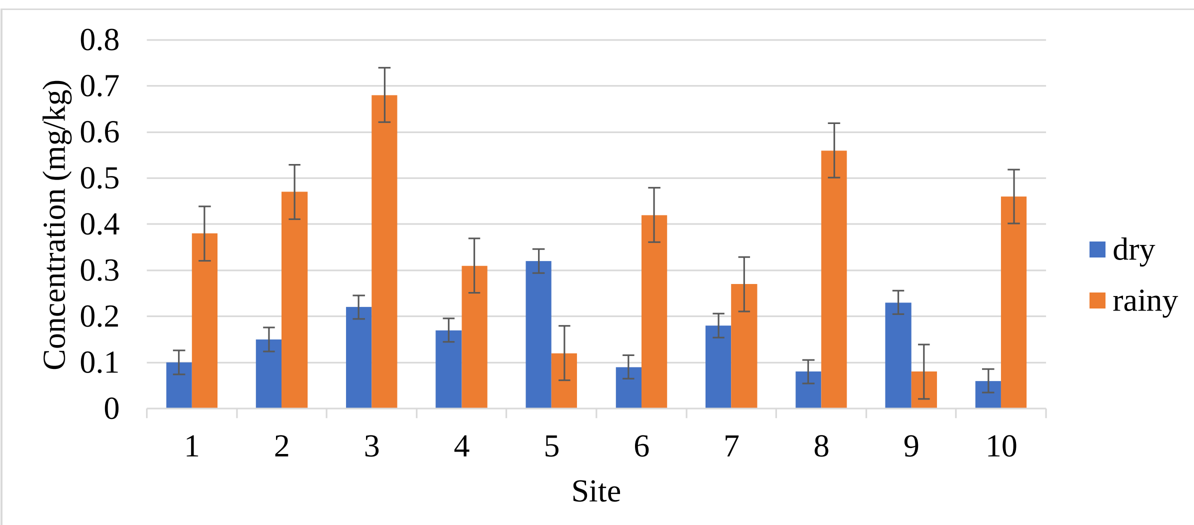

Figure 6. Phosphorous levels in soil samples

Potassium levels in all sites except Site 6 were higher during rainy than dry season (Figure 7). The mean level of available potassium in soil was significantly higher in rainy season than dry season (Table 3). This variation can be due to addition of fertilizers containing potassium during rainy season. In addition, rain helps the shift of potassium from slowly available forms to readily available forms, hence during rainy season the potassium level in soil is higher than in dry season[30]. Similar variation undertaken by Blenchet and his team attributed it to fertilizers as the main source of available potassium in soils during wet season [37]

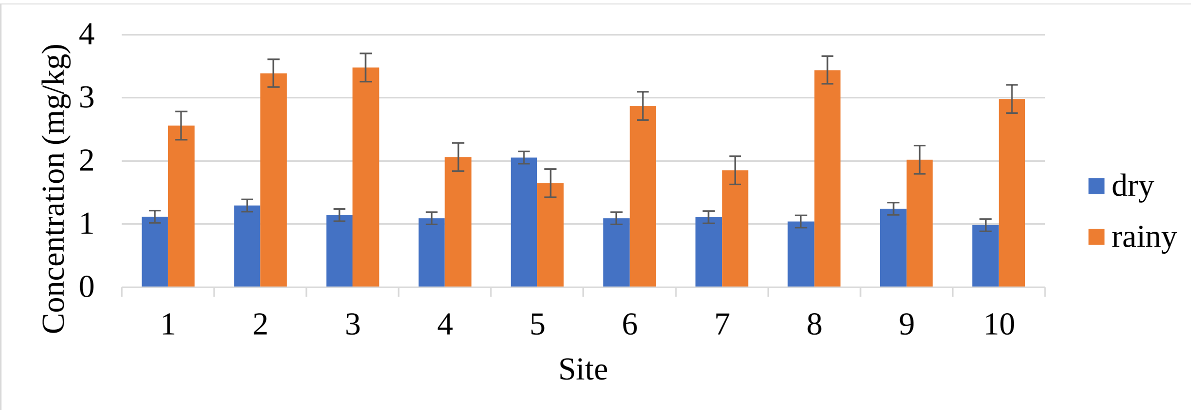

Figure 7. Potassium levels in soil samples

3.3. Correlation results

Table 4. Bivariate Pearson correlation between any two parameters of soil in dry and wet seasons

Dry season						
	pH	MC	EC	NO_3-N	PO_3-P	K
pH	1					
MC	-.089	1				
EC	-.177	.909**	1			
NO_3-N	-.194	-.610	-.532	1		
PO_3-P	-.162	.942**	.931**	-.514	1	
K	-.111	.681*	.742*	-.578	.796**	1
Rainy season						
	pH	MC	EC	NO_3-N	PO_3-P	K
pH	1					
MC	.359	1				
EC	.521	.787**	1			
NO_3-N	-.528	-.335	-.402	1		

PO_3-P	.456	.759*	.899**	-.480	1	
K	.446	.617	.731*	-.504	.912**	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

The results in Table 4 show that moisture content (MC) had strong significant positive correlations with EC in dry (R^2= 909) and wet (R^2=787) seasons. This is possible because as moisture content increases, the number of soluble salts increases and hence electrical conductivity[38]. Moisture content also had positive correlations with phosphorous in both seasons and potassium in dry season. The available phosphorous in soil exist in the form of HPO_4^{2-} and $H_2PO_4^-$ ions[35]. Salts containing these ions in the soil are very soluble, hence the positive correlation between moisture content and available phosphorous.

Electrical conductivity presented positive significant correlations with phosphorous and potassium in both seasons and this is associated with the use of N-P-K fertilizers which increase the level of salts in soil. Phosphorous in both seasons were strongly positively correlated ($P<0.01$) with potassium and this is an indication that phosphorous and potassium were from same source and the possible source in this study is the application of inorganic fertilizers.

IV. Conclusion

The results of the analyzed parameters of soil samples collected at different tea farms along Sulal River showed the soils in both seasons had low major nutrients and this explains the application of fertilizers by the inhabitants. The soil samples were moderately acidic in both seasons. Soil acidity in tea plantations is attributed to continuous heavy application of chemical fertilizer[39]. Significant correlations were observed between MC and EC, MC and PO_3-P, MC and K, EC and PO_3-P, EC and K, and PO_3-P and K. The mean levels of pH, electrical conductivity, moisture content, and potassium in dry and rainy seasons were significantly different ($p<0.05$). This indicates that rainfall had a great effect on levels of some soil physicochemical parameters. Stringent legislation on management of soils along the rivers is recommended by Kericho County and Kenya governments

V. References

1. World Bank. (2019). Kenya Economic Update: Transforming Agricultural Productivity to Achieve Food Security for All. Kenya Economic update https://www.worldbank.org/en/country/kenya/publication/kenya-economic-update-transforming-agricultural-productivity-to-achieve-food-security-for-all. Link valid on 6th March 2020

2. Kenya County Climate Risk Profile Series, KCCRP. (2018). Climate Risk Profile for Kericho County. Retrieved from https://ccafs.cgiar.org/publications/kenya-county-climate-risk-profiles. Link valid on 23rd May 2020.

3. Njogu, R. N. E., Kariuki, D. K., Kamau, D. M., and Wachira, F. N. (2015). Economic evaluation of foliar NPK fertilizer on tea yields in Kenya. Journal of Plant Studies, **4**(1), 35-39.

4. Kamunya, S., Ochanda, S., Cheramgoi, E., Chalo, R., Sitienei, K., Muku, O., ... and Bore, J. K. (2019). Tea Growers Guide.

5. Mosier, A., Syers, J. K., and Freney, J. R. (Eds.). (2013). Agriculture and the nitrogen cycle: assessing the impacts of fertilizer use on food production and the environment. Island Press, Washington, London: Vol 65, pp. 130-157

6. Khan, M. N., Mobin, M., Abbas, Z. K. and Alamri, S. A. (2018). Fertilizers and their contaminants in soils, surface and groundwater. In: Dominick A. DellaSala, and Michael I. Goldstein (eds.) The Encyclopedia of the Anthropocene, Oxford: Elsevier, vol. 5, pp. 225-240.

7. Somasundaram, J., Singh, R. K., Parandiyal, A. K., Ali, S., Chauhan, V., Sinha, N. K.& Simaiya, R. R. (2013). Soil properties under different land use systems in parts of Chambal region of Rajasthan. Journal of Agricultural Physics, *13*(2), 139-147.

8. Liu, E., Yan, C., Mei, X., He, W., Bing, S. H., Ding, L., Fan, T. (2010). Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. Geoderma, **158**:173–180.

9. Carter, M., and Bentley, S. P. (2016). *Soil properties and their correlations*. John Wiley and Sons

10. Kiboi, M. N., Ngetich, K. F., Fliessbach, A., Muriuki, A., and Mugendi, D. N. (2019). Soil fertility inputs and tillage influence on maize crop performance and soil water content in the Central Highlands of Kenya. Agricultural water management, **217**, 316-331.

11. Guo, T., Gill, D., Johengen, T. H., and Cardinale, B. L. (2019). What determines the public's support for water quality regulations to mitigate agricultural runoff? Environmental Science and Policy, **101:** 323-330.

12. Stein, L. Y., and Klotz, M. G. (2016). The nitrogen cycles. Current Biology, **26**(3), 94-98

13. Maghanga, J. K., Kituyi, J. L., Kisinyo, P. O., and Ng'etich, W. K. (2012). Impact of nitrogen fertilizer applications on surface water nitrate levels within a Kenyan tea plantation. Journal of Chemistry, **16**, 36-40

14. Basweti, J. K., Nawiri, M. P., and Nyambaka, H. N. (2018). Physico-chemical parameters and levels of polycyclic aromatic hydrocarbons in water, sediments and soil in River Nzoia, Kakamega county-Kenya. Environmental monitoring and assessment, **190**(9), 518-524.

15. Lewis Jr, W. M., Wurtsbaugh, W. A., and Paerl, H. W. (2011). Rationale for control of anthropogenic nitrogen and phosphorus to reduce eutrophication of inland waters. Environmental science and technology, **45**(24), 10300-10305.

16. Cherotich, S., Abong'o. D. A., and Onyatta, J. O. (2021). Assessing the Seasonal Changes on Physicochemical Parameters and Major Nutrient Levels in water and Sediments from Sulal River, Bureti Sub-County, Kericho County, Kenya. Chemical Science International Journal, **30** (1), 46-58.

17. Koskei, R. C. (2012). Access and use of information by small holder tea farmers in Bureti District, Kenya (PhD Thesis, Egerton University, Kenya

18. Ministry of Foreign Affairs (MoFA) (2019). Climate Change Profile: Kenya retrieved from https://www.government.nl/documents/publications/2019/02/05/climate-change-profiles. Link valid on 23rd May 2020.

19. Okalebo, J. R., Gathua, K. W., and Woomer, P. L. (2002). Laboratory methods of soil and plant analysis. A working manual, **2**:29-68.

20. Willson, K. C., and Clifford, M. N. Eds. (2012). *Tea:* Cultivation to consumption. Springer Science and Business Media, pp. 269-334.

21. Watros, A., Lipińska, H., Lipiński, W., Tkaczyk, P., Krzyszczak, J., Baranowski, P., and Jackowska, I. (2019). The relationship between mineral nitrogen content and soil pH in grassland and fodder crop soils. Applied Ecology and Environmental Research**, 17**(1), 107-121.

22. Bünemann, E. K., Oberson, A., and Frossard, E. (Eds.). (2010). Phosphorus in action: biological processes in soil phosphorus cycling. Springer Science and Business Media, Vol 26, pp. 199-214.

23. Borowik, A., and Wyszkowska, J. (2016). Soil moisture as a factor affecting the microbiological and biochemical activity of soil. Plant, Soil and Environment, **62**(6), 250-255.

24. Munivenkatappa, N., Sarikonda, S., Rajagopal, R., Balakrishnan, R., and Nagarathana, C. K. (2018). Variations in quality constituents of green tea leaves in response to drought stress under south Indian condition. Scientia horticulturae, **233:** 359-369.

25. Nyaboke, O. P. (2013). Concentration of selected nutrients and heavy metals in soils in tea farms and water from Nnyamasogota River, Kisii County, Kenya (Msc Thesis, Kenyatta University).

26. Ma, L., Shi, Y., and Ruan, J. (2019). Nitrogen absorption by field-grown tea plants (Camellia sinensis) in winter dormancy and utilization in spring shoots. Plant and Soil, **442**(1-2), 127-140.

27. Ruto, R., Kebeney, S., Bore, J. K., and Chemei, D. (2019). Impact of Seasons on Soil Physico-chemical properties and tea yields based on enriched sheep manure used in Kericho, Kenya. Journal of Agricultural Chemistry and Environment, **8** (3),184-199.

28. Kunwar, V. S., Lamichhane, J., and Gauchan, D. P. (2018). Strategies to improve phosphorus availability in a sustainable agricultural system. International Journal of Innovative Science and Research Technology, **3**(9), 323-331.

29. Mucheru-Muna, M., Mugendi, D., Pypers, P., Mugwe, J., Kung'u, J., Vanlauwe, B., and Merckx, R. (2014). Enhancing maize productivity and profitability using organic inputs and mineral fertilizer in central Kenya small-hold farms. *Experimental Agriculture*, **50**(2), 250-269.

30. Majumdar, K., Roberts, T., Pates, P., Shirley, S., Prochnow, L., Fixen, P., and Smith, C. (2017). Potassium Losses and Transfers in Agricultural and Livestock Systems. In: Murrell, T.S. and Mikkelsen, R. L. (Eds.). Frontiers of Potassium Science Conference, International Plant Nutrition Institute, Peachtree Corners, GA, USA, pp. 166-172.

31. McCauley, A., Jones, C., and Jacobsen, J. (2009). Soil pH and organic matter. Nutrient management module, *8*(2), 1-12.

32. Baruah, B. K., Das, B., Medhi, C., and Misra, A. K. (2013). Fertility status of soil in the tea garden belts of golaghat district, Assam, India. Journal of Chemistry, 2013.

33. Maqsood, M. A., Awan, U. K., Aziz, T., Arshad, H., Ashraf, N., and Ali, M. (2016). Nitrogen management in calcareous soils: problems and solutions. *Pakistan* Journal of Agricultural Sciences, **53**(1), 79-95.

34. Jacobs, S. R., Breuer, L., Butterbach-Bahl, K., Pelster, D. E., and Rufino, M. C. (2017). Land use affects total dissolved nitrogen and nitrate concentrations in tropical montane streams in Kenya. Science of the Total Environment, **603**, 519-532.

35. Lal, R., and Stewart, B. A. (Eds). (2016). Soil phosphorus. CRC Press.

36. Zheng, Z., He, X., and Li, T. (2012). Status and evaluation of the soil nutrients in tea plantation. Procedia Environmental Sciences, **12**, 45-51.

37. Blanchet, G., Libohova, Z., Joost, S., Rossier, N., Schneider, A., Jeangros, B., and Sinaj, S. (2017). Spatial variability of potassium in agricultural soils of the canton of Fribourg, Switzerland. *Geoderma*, **290**, 107-121.

38. Costa, M. M., Queiroz, D. M. D., Pinto, F. D. A. D. C., Reis, E. F. D. and Santos, N. T. (2014). Moisture content effect in the relationship between apparent electrical conductivity and soil attributes. Acta Scientiarum. Agronomy, **36**(4), 395-401.

39. Owuor, P. O., Othieno, C. O., Kamau, D. M., and Wanyoko, J. K. (2011). Effects of long-term fertilizer use on a high-yielding tea clone AHPS15/10: soil pH, mature leaf nitrogen, mature leaf and soil phosphorus and potassium. International Journal of Tea Science, **8**(1), 15-51.