Seasonal Variation of Major Inorganic Nutrients and Selected Physicochemical Parameters Levels in Soil from the Athi - Thwake River Catchment Area, Makueni County, Kenya

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ABSTRACT

This study evaluated selected physicochemical parameters and major inorganic nutrients of soil samples from ten specific sites in the Athi-Thwake River catchment area in November 2021 and January 2022 in Makueni County representing wet and dry seasons respectively. The average levels of the physicochemical parameters in the dry and wet seasons, for pH were 4.63 ± 0.25 and 4.43±0.18, electrical conductivities were 122±8.09 µS/cm and 216±2.70 µS/cm, percentage moisture contents were 14.19 ± 0.40 % and 27.92±0.56 % while the major inorganic nutrients levels were, nitrate-nitrogen at 0.24±0.04 mg/kg and 0.37±0.02 mg/kg, phosphate-phosphorous were 0.08±0.05 mg/kg and 0.07±0.03 mg/kg and potassium 1.02±0.15 mg/kg and 1.05±0.35 mg/kg respectively. In the two seasons; pH, electrical conductivities and moisture contents levels had no statistical difference with nitrate-nitrogen, phosphate-phosphorous and potassium (p>.05). The soil samples in both seasons had low major nutrients contents, indicating that the area is already experiencing significant erosion. To prevent further nutrient loss due to water runoff and leaching, soil conservation practices such as contour farming, terracing and cover cropping should be implemented to reduce erosion and retain nutrients in the soil.

Keywords: Soil physicochemical parameters, major inorganic nutrient, Athi-Thwake River catchment, Makueni County, Kenya.

INTRODUCTION

Kenya is an agriculturally developing nation, and its economy is based mainly on farming [1]. Over time, the government of Kenya has devised ways to ensure food security in the country. One strategy is to construct dams for irrigation in different counties, including Mwache in Kwale, Soin Koru in Kisumu-Kericho, Kabazi in Nakuru, and Thwake in Makueni.

Agriculture and mining are the primary economic activities in the Makueni area [1], where the Thwake Dam is located in a semi-arid region with annual rainfall averaging around 690 mm. Irrigation is one of the main purposes for the construction of the Thwake Dam. The soil's nutritional content primarily comes from inorganic fertilizers containing potassium, nitrogen and phosphorus [2]. Most Kenyan farmers currently prefer inorganic fertilizers over organic ones [3] because inorganic fertilizers release nutrients faster and result in higher crop yields [4], [5]. Soil moisture is a key factor affecting nutrient availability and transformation, as nutrient absorption in dry soil is significantly lower than in moist soil [6], [7]. High moisture content can also reduce the activity of soil microorganisms that are crucial for organic matter decomposition [8].

Soil pH plays an important role in plant growth and productivity by influencing nutrient availability [9], [10].

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Highly acidic soil can be toxic to plants, as it leads to the formation of compounds that are unavailable for plant uptake [11]; [12]. Electrical conductivity (EC) serves as an indicator of soil health, with optimal EC levels ranging between 110-570 mS/m. Low EC indicates insufficient nutrients, while high EC suggests an excess of nutrients [13]. Nitrogen in soil is naturally derived from the decomposition of vegetation residues [14]; [15], while phosphorus exists in both organic and inorganic forms. Organic phosphorus, found in manure, plant residues, and microorganisms, is absorbed directly by plants, whereas inorganic phosphorus exists as orthophosphates in fertilizers [12]; [16].

The major sources of accumulation of nutrients in soil are from agricultural farms due to the possibility of the runoff containing residual fertilizers and the geology of the catchment area [17]. In contrast, smaller rivers feeding the small-scale agricultural farm have higher levels of chemical nutrients than those from agricultural farms. Soil quality is paramount in ensuring sustainable agriculture and safeguarding environmental health. Major nutrients and physicochemical parameters including; nitrogen, phosphorus, potassium, pH, electrical conductivity, and moisture content are crucial for the growth of crops and productivity [18].

This study aimed to determine the levels of major inorganic nutrients and physiochemical parameters in soil from the Athi-Thwake River catchment area in Makueni County

MATERIALS AND METHODS

The Study Area

The construction of the Thwake Multipurpose dam was proposed and implemented by Kenya's Ministry of Water, Sanitation and Irrigation. The Dam (Figure 1) is located in Makueni County at a distance of about 180 km from Nairobi City and can be accessed from Wote Town through Mavindini via Mikisi Primary School [19]. The Thwake Dam project area is located on a slightly uneven landscape with a consistent slope towards the northeast. The dam is located in an arid and semi-arid area characterized by low levels of rainfall averaging about 690 mm per annum. The total length of the area of study is 22 km, area covered by the dam is 29 km^2 across a bridge from the bank to about 9 km^2 upstream, an estimated catchment area of 10, 276 km^2 and it lies between Latitude $1^0$47ˈ42.8” S and Longitude 37°50’17.3” E [19].

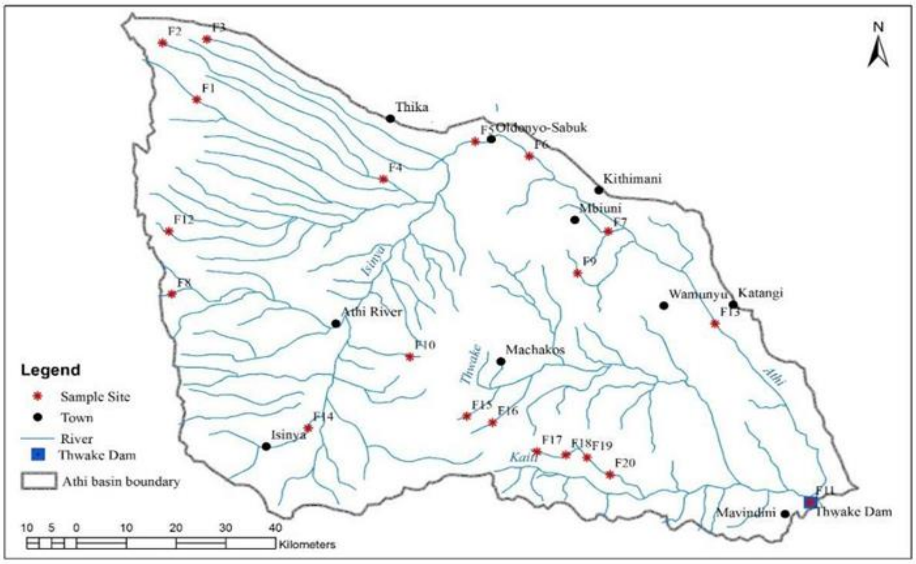

Figure 1: Map of Athi -Thwake River Catchment Area Showing Sampling Sites

Soil Samples Collection

As shown in Figure 1, soil samples were collected from 10 sites in November 2021 and January 2022 representing wet and dry seasons respectively. At each site, samples were collected from five locations within the selected farms by digging to a depth of 0-30 cm using a hoe and 800 g of soil samples were scooped using a spade. The soil samples were thoroughly mixed on sterilized aluminum foil to form a composite sample.

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From this composite, four sets of 1,000 g samples were taken. The sampling site with coordinates and human activities in the study area as shown in Table 1. Four sets of 1000 g samples were taken from each of the sampling sites. For each site, two sets were designated as Batch A. These sets were individually wrapped in sterilized aluminum foil, marked, and put in marked self-sealing polyethylene bags. They were then taken to the Department of Chemistry, University of Nairobi, for pH, Electrical conductivity, moisture contents and major nutrients (chemical properties) analysis.

Table 1: Description of the sampling sites, coordinates and human activities in the study area

Local Name	Site	Latitude	Longitude	Altitude (m)	Description
Kikesa	F_7	1°15'44.5"S	37°27'51.4"E	1192	Shrub (Acacia), banana plantation, maize, Millet, sorghum and beans and flat area
Mwala	F_9	1°21'33.8"S	37°23'48.3"E	1438	Fruits and crop production like mango, maize, beans and traditional foods like cassava, sweat potatoes and sorghum, types of livestock are zebu cattle, dairy cattle and small-scale poultry.
Mavindini, Ngosini East	F_{11}	1°47'40.5"S	37°49'47.8"E	921	Shrubs and indigenous trees. rocky and Hilly area.
Oloika, Road, Kiserian	F_{13}	1°23'53.3"S	36°41'27.2"E	1879	Horticultural farming through irrigation and green house, types of livestock goats. flat area
Lubwa, kwa Kavoo	F_{15}	1°37'31.8"S	37°12'30.6"E	1642	Acacia trees (Shrubs). flat area
Lubwa, muumandu area	F_{16}	1°38'15.7"S	37°15'18.6"E	1764	Acacia trees (Shrubs). flat area
Machakos Wote Road, Lanzoni	F_{17}	1°41'42.2"S	37°20'06.0"E	1620	Shrubs, mangoes, plantation, banana plantation. hilly area
Machakos Wote Road, Kola	F_{18}	1°43'05.0"S	37°22'06.4"E	1564	shrubs, mangoes plantation, banana plantation, maize plantation. hilly area
Makongo	F_{19}	1°42'43.6"S	37°24'04.1"E	1570	Acacia(shrub), hilly and Rocky and sand collection area.
Machakos Wote Road, mukuyuni	F_{20}	1°43'17.3"S	37°25'08.4"E	1400	Acacia trees (Shrubs). hilly area

Chemicals and Reagents

Buffers with pH values of 2, 4, 7, and 10, potassium chloride (99.0 %), potassium dihydrogen phosphate (99.9 %), distilled water, potassium sulphate (99.0 %), sodium hydroxide (98.0 %), sodium bicarbonate (98.0 %), Ammonium Molybdate (99.9 %), antimony potassium tartrate (98.0 %), sulfuric acid (97 %), salicylic acid (99.0 %). These reagents and standards were manufactured by Sigma-Aldrich Company, USA.

Instrument and Apparatus

Equipment used included an analytical balance (Shimadzu, serial no. C054-E032Q), mechanical/orbital shaker, pH-EC-TDS meter serial no: (HANNA 9812), flame photometer (EEL 100), laboratory glassware and bags, spatula and pH meter (Jenway 3540 pH & conductivity meter) and UV-VIS spectrophotometer.

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pH Determination

The pH meter was switched on to ensure that it warmed up approximately 10 minutes and had been calibrated at room temperature using buffers with pH values of 2, 4, 7, and 10. To determine the sample's pH, homogenized sieved samples each weighing 20 g were mixed with 50 ml distilled water in a 100 ml beaker of distilled water. Additional water was added to create a 5:2 ratio of water and soil respectively. An orbital shaker running for 15 minutes at 15 revolutions per minute (rpm) was used to shake the solution mechanically. After 15 minutes, a cleaned and dried electrode was inserted into the suspension for pH measurement, and the reading was taken. The results were recorded in triplicate, and the average was stated as the pH for all samples.

Electrical Conductivity determination

A HANNA 9812 conductivity meter, calibrated with 0.01 and 0.10 N potassium chloride in deionized distilled water was used to examine the ability of the samples to conduct electricity. To create a 1:5 soil-water mixture, around 20 g of each homogenized, sieved sample was added to a labeled beaker along with 100 ml of deionized water. For one hour, this suspension was shaken mechanically at 15 revolutions per minute. The conductivity meter's electrodes were cleaned with deionized distilled water before being submerged in the samples. Each sample's ability to conduct electrical currents was examined in triplicate for the samples of water, and the average result was recorded.

Moisture Content Determination

The measurement container was denoted as (W1). 50 g samples of soil were weighed in the weighing container (W2) and oven-dried for 24 hours and left for cooling in the desiccator. The container and soil sample content were weighed (W3). The Moisture content percentage was calculated using equation 2.1

% Moisture Content $= \frac{W2-W3}{W3-W1} * 100$ Equation 2.1

Where

W1= the container's mass

W2 = the mass of the container and wet soil samples

W3 = the mass of container and dry soil samples

Nitrate, Phosphate and Potassium Standard Solutions Preparation

Nitrate Standard Solution Preparation**:** Potassium nitrate (KNO_3) of 7.223 g was weighed after drying at 105°C and was put in a 100 mL beaker to create a nitrate-nitrogen solution. After that, a concentration of 1000 µg N/mL was achieved by transferring this to a one-liter volumetric flask and adding distilled water until full. In a 500 mL volumetric flask, 25 mL of the combination were diluted with water that has been distilled to generate a standard solution with a concentration of 50 µg N/mL. Different standard solutions ranging from 0 to 10 µg N/mL were generated by putting 0 to 10 mL of this solution into labeled 100 mL volumetric flasks and filling them with deionized distilled water. The absorbance of these standards was determined using UV-VIS spectrophotometer at 419 nm. The absorbances were then used to create calibration curves for nitrate for analyzing nitrogen-nitrate levels in soil samples from the analysis of the absorbance values and corresponding standard concentrations.

Phosphate Standard Solution Preparation: A 100 mL beaker was used to weigh 2.197 g of potassium dihydrogen phosphate and then poured completely into a 1000 ml volumetric flask for the preparation of phosphate-phosphorus solution after being dried at 100°C for two hours. Deionized water was poured to the flask until the concentration reached 500 µg P/mL. A standard solution of 100 µg P/mL was generated after diluting 50 mL of this solution with deionized distilled water in a 250 mL volumetric flask. Various standard solutions ranging from 0 to 5 µg P/mL were generated by putting 0 to 25 mL of this standard solution into

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labeled 500 mL volumetric flasks and filling them with deionized distilled water. The absorbances of these solutions were examined at 882 nm by a UV-VIS spectrophotometer, and the observed values and standard concentrations were utilized for constructing calibration curves for phosphorus, which were used to analyze phosphorus levels in soil samples.

Potassium Standard Solution Preparation: 1.907 g of potassium chloride were weighed into a 100 mL beaker for the preparation of potassium solution after being dried at 100°C for two hours. To get a concentration of 1000 µg K/mL, the solution was transferred to a one-liter volumetric flask and filled with deionized distilled water after adding 10 mL of diluted HCl. 100 µg K/mL was the concentration of the standard solution, which was produced by diluting 10 mL of the stock solution with deionized distilled water in a 100 mL volumetric flask. Labeled 100 mL volumetric flasks were filled with distilled water after 0 to 4 mL of the standard solution, spanning from 0 to 4 µg K/mL, were transferred into them. Using a Flame Photometer at a wavelength of 767 nm, the concentrations were analyzed, and the emission values and standard concentrations were used to make a calibration curve for potassium, which was used to analyze potassium levels in soil samples.

Data Analysis

Statistical program for social scientists (IBM SPSS Version 20) was used to perform the analyses; descriptive statistics were used to obtain the mean and standard deviation of the sample in triplicates for each parameter: Bivariate Pearson's correlation (r) value was used to show the degree of association between the selected physicochemical parameters (pH, EC, and MC) and the major nutrients (NPK), and the paired sample test was used to compare the means in the levels of NPK between dry and wet seasons. Differences were regarded to be significant at 95 % confidence limit.

RESULTS AND DISCUSSIONS

Soil physicochemical parameter and major nutrients levels in dry and wet seasons

For each soil sample, the following parameters were measured in triplicate (n=3): pH, electrical conductivity (EC), moisture content and the major inorganic nutrients including nitrates, phosphates and potassium levels. Table 2 presents the average values of these analytical parameters in the rainy and dry seasons from each of the ten distinct sites that were chosen.

Table 2. Soil physiochemical parameters and nutrients levels in the dry and wet season

Dry Season						
Site	pH	EC (µS /cm)	Moisture Content (%)	NO_3^- N (mg/kg)	PO_4^- P (mg/kg)	K (mg/kg
F7	4.80 ± 0.22	150 ±5.20	14.30 ±0.40	0.56±0.06	1.0 ±0.04	1.02 ±0.15
F9	4.60 ±0.08	190 ±8.40	14.78 ±0.40	0.89±0.10	0.18 ±0.03	1.19 ±0.20
F11	4.50 ±0.01	245±6.50	21.92±0.30	0.60 ±0.02	1.50 ±0.04	2.16 ±0.01
F13	4.64 ±0.04	189 ±3.89	18.87±0.20	0.54 ±0.03	0.22 ±0.08	1.07 ±0.20
F15	4.76 ±0.03	182± 4.70	16.96± 0.26	0.24±0.04	0.17 ±0.02	1.10 ±0.30
F16	4.53 ±0.08	230±6.20	14.19 ±0.40	0.67±0.02	0.40 ±0.04	1.04 ±0.20
F17	4.07 ±0.04	122 ±8.09	19.20 ±0.30	0.79± 0.03	0.19 ±0.08	1.24 ±0.30
F18	4.55 ± 0.02	135 ±2.83	20.45 ±0.50	0.89±0.08	0.08 ±0.05	1.08 ±0.60
F19	4.86 ±0.01	171±5.30	21.01 ±0.40	0.15±0.04	0.23 ±0.02	1.22 ±0.70

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F20	4.98 ±0.05	148± 5.50	14.34 ± 0.75	0.59±0.03	0.40 ±0.03	1.98 ±0.10
M ± SD, n = 10	4.63±0.25	176.2±39.66	17.60±3.06	0.59±0.25	0.44±0.46	1.31±0.41
Wet season						
F7	4.55 ±0.08	220 ±5.23	27.92 ±0.56	0.43 ± 0.03	0.38 ±0.07	2.26 ±0.11
F9	4.47 ±0.01	240±4.50	33.95 ±0.35	0.54 ±0.02	0.47 ±0.04	2.29 ±0.21
F11	4.42 ±0.09	290±6.30	38.55 ±0.42	0.90 ±0.03	1.00 ±0.03	3.48 ±0.19
F13	4.25 ±0.07	250±6.20	32.82 ±0.34	0. 63 ±0.01	0.18 ±0.02	2.06 ±0.23
F15	4.18 ±0.06	262 ±6.45	34.32 ± 0.62	0.37 ±0.02	0.11 ±0.07	1.05 ±0.35
F16	4.77 ±0.04	259±5.40	34.38 ±0.02	0.61 ±0.09	0.12 ±0.01	2.85 ±0.23
F17	4.24 ±0.06	254 ±3.30	33.38 ±0.04	0.38 ±0.08	0.13 ±0.08	2.44 ± 0.20
F18	4.58 ±0.08	216 ±2.70	30.16 ±0.20	0.81 ±0.07	0.07 ±0.03	2.63 ±0.24
F19	4.44 ±0.01	219 ±2.10	34.40 ±0.44	0.83 ±0.08	0.21 ±0.02	2.88 ±0.20
F20	4.41 ±0.02	263 ± 4.80	28.00 ±0.70	0.89 ±0.09	0.33 ±0.04	2.99 ±0.70
M ± SD, n = 10	4.43±0.18	247.30±23.70	32.79±3.26	0.64±0.21	0.30±0.28	2.49±0.66
WHO Limits	6.0-8.5	4000	Specific to crop/region	50	Not specific	Not specific
KEBS Limits	5.5-7.5	2000	Specific to crop/region	50	40	250

pH of soil samples

The soil pH results analyzed in samples from 10 selected sites in the rainy and dry seasons are in Table 2 and Figure 2

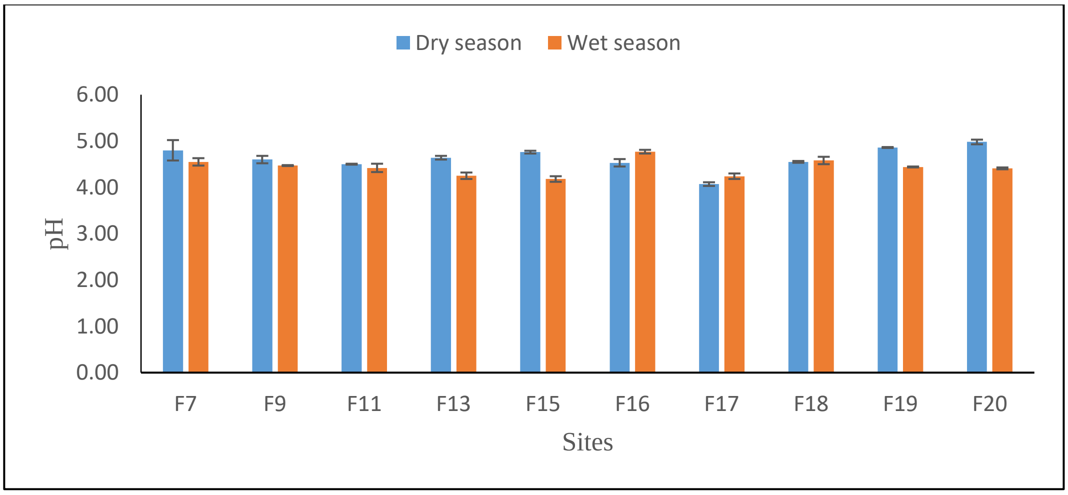

Figure 2: Soil Samples pH levels from the ten selected sites in dry and wet seasons

The pH of soil samples exhibited variation, with values ranging from 4.07±0.25 - 4.98±0.18 in the dry and 4.18±0.06 - 4.77±0.04 for wet seasons (Table 2). This pH range, observed in both seasons, indicates a significant degree of acidity [20]. Consequently, in both seasons, the pH falls below the critical threshold of

5.5, suggesting a probable presence of exchangeable Al^{3+} ions that contribute to lowering the pH of soil by releasing hydrogen ions as noted by [20].

Electrical Conductivity

The soil's potential to conduct electric currents results as analyzed in soil samples collected from 10 varied study location in both the rainy and dry seasons are shown in Figure 3.

The soil's ability to conduct electrical currents ranged from 122±8.09 - 245±6.50 µS/cm in the dry and 216±2.70 - 290±6.30 µS/cm in wet season (Table 2). Dissolved salts, minerals, and ions [21] influence these values. Figure 3 shows that electrical conductivity (EC) was lower in the dry across all sites than wet season. This variation is due to differing nutrient levels and higher moisture content in the wet season, which increases dissolved ions and EC, as noted by [22] and [23].

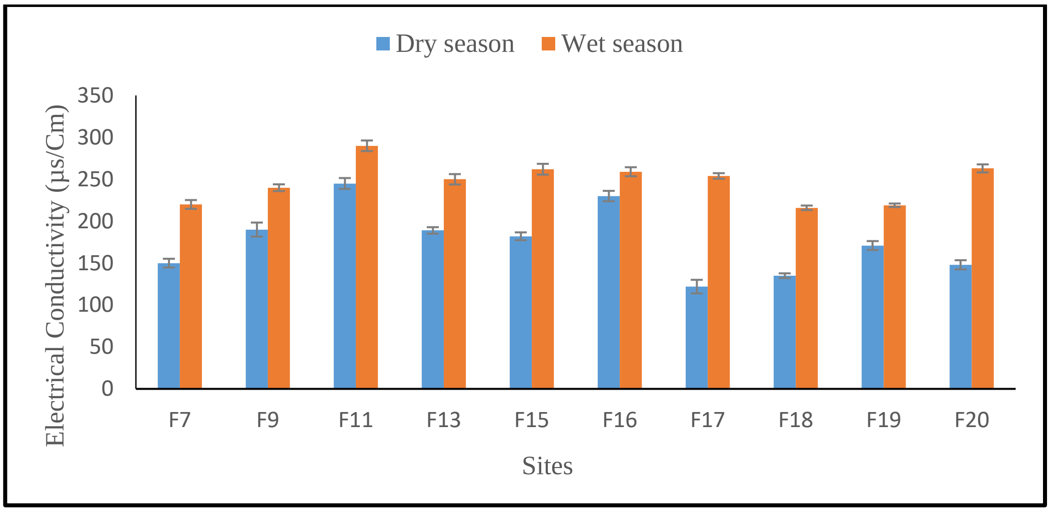

Figure 3: The Soil Electrical Conductivity levels from the ten selected sites in dry and wet seasons

Moisture content

Table 1 shows soil moisture content (MC) ranging from 14.19±0.40 % - 21.92±0.30 % in the dry and 27.92±0.56 % -38.55±0.42 % in the wet seasons. Moisture content plays a key role in soil health, influencing biological, physical, and chemical processes [24]. Figure 4 shows lower moisture content in the dry season, with Site F11 having the highest at 21.92 ± 0.30 % and F16 the lowest at 14.19 ± 0.40 %. In the wet season, Site F11 had the highest at 38.55 ± 0.42 % and F7 the lowest at 27.92 ± 0.56 %. These variations are due to topography, vegetation, and organic matter [25]. Moisture reductions affect nutrient absorption, as organic matter breaks down, converting nitrogen and phosphorus into their inorganic forms [8].

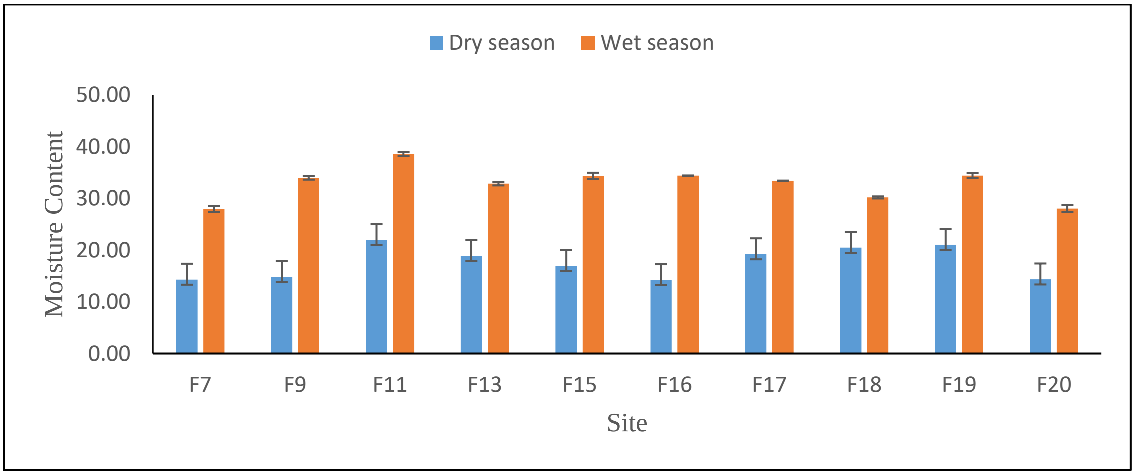

Figure 4: Percentage Soil moisture content levels from the ten selected sites in dry and wet seasons

The Correlation Results

Table 3 shows a non-significant correlation ($p > 0.05$) between pH and soil nutrients, with NPK levels not affecting pH in either season. While there is a weak positive correlation of 0.037 between pH and phosphorus, it suggests no meaningful linear relationship. A very weak positive correlation exists between pH and potassium at 0.121, though a stronger correlation was shown in the wet season. Electrical conductivity (EC) showed significant positive correlations with all nutrients except nitrogen in the dry season, indicating that higher EC corresponds with increased nutrient levels. No significant correlation ($p > 0.05$) was found between soil nutrients and moisture content in either season (Table 3).

Table 3: 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		1		-0.168	0.118	0.218
EC			1	-0.115	0.484	0.277
NO_3-N	-550			1		
PO_3-P	0.037				1	
K	0.121					1
Wet Season						
	pH	MC	EC	NO_3-N	PO_3-P	K
pH	1					
MC		1		0.074	0.424	0.144
EC			1	0.106	0.51	0.171
NO3-N				1		
PO3-P					1	
K						1

The Nitrogen levels in the soil samples

Table 4, shows that nitrogen levels in soil samples exhibited variations in wet and dry seasons since $p> 0.05$. In the dry season, the nitrogen levels ranged from 0.15 ± 0.04 - 0.89 ± 0.10 mg/kg, while the values in the rainy season were within the range of 0.37±0.02 - 0.89±0.09 mg/kg (Table 2).

With the exception of soil samples collected from Sites F11, F13, F15, F19 and F20, in the wet season, the levels of nitrogen were higher and lower in the dry season (Figure 5). The lack of moisture in the soil can hinder the growth and activity of microorganisms responsible for breaking down organic matter and releasing nitrogen into the soil. This reduction in microbial activity may contribute to the observed lower nitrogen soil levels, as discussed by [23].

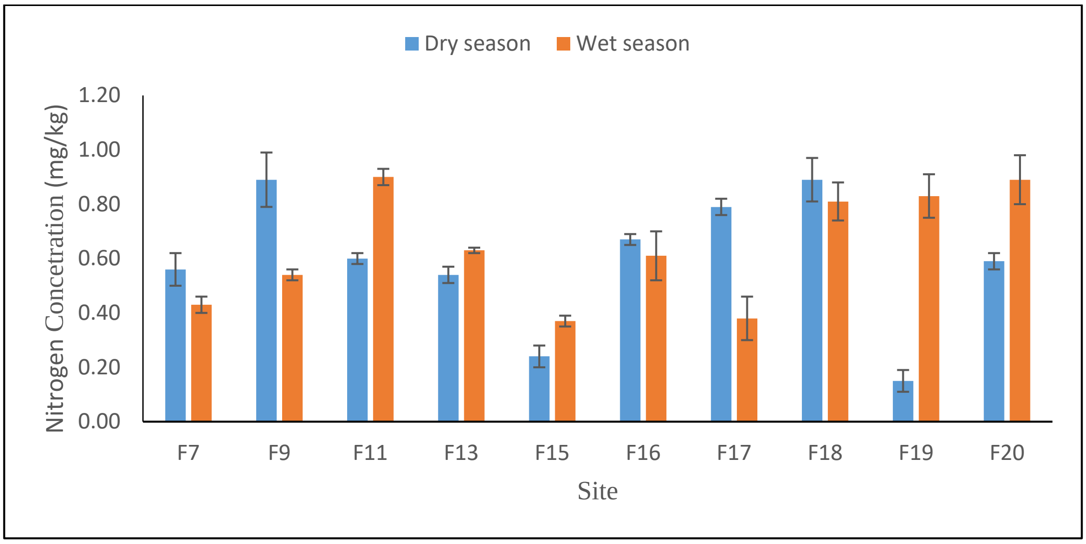

Figure 5: Nitrogen levels in the soil samples in the dry and wet seasons

Table 4: Paired sample T test for analytes and mean levels in soil during dry and wet seasons

Pairs		t	df	Sig. (2-tailed)
NO_3-N	dry - rainy	.454	9	.660
PO_3-P	dry - rainy	-1.646	9	.13
K	dry - rainy	-7.287	9	<.001

The Phosphorus Levels in soil samples

In Table 2, it is evident that the phosphorus levels in soil samples exhibited variations between the dry and wet seasons. In the dry season, the phosphorus levels ranged from 0.08 ± 0.05 - 1.50 ±0.04 mg/kg, whereas in the rainy season, the values were within the range of 0.07 ± 0.03 - 1.00±0.03 mg/kg. From Table 4: $p>0.05$ showed that the difference is not statistically significant. In general, the phosphorus levels are higher in the dry season compared to the wet season, with the exception of Site F9 (Figure 6). Nevertheless, it's worth noting that these values display significant variability, which could be attributed to differences in soil types, land use, or other influencing factors, as suggested by [26].

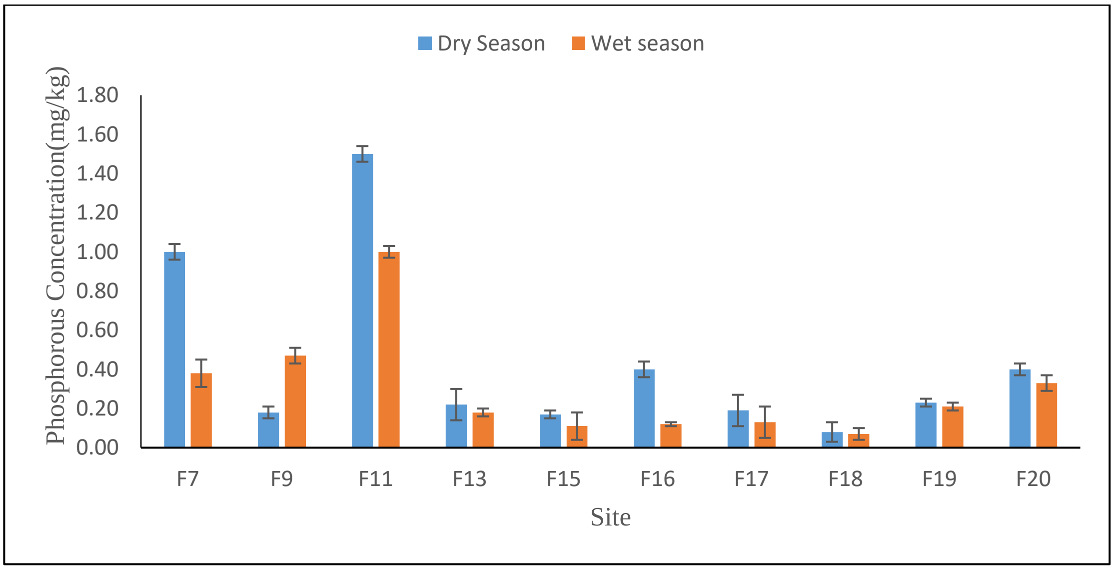

Figure 6: The phosphorous levels in soil samples

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The Potassium levels in soil samples

In Table 2, the potassium levels in soil samples exhibit variations between the dry and rainy conditions. Specifically, in the dry conditions, the potassium levels ranged from 1.02±0.15 mg/kg - 2.16±0.01 mg/kg, while in the rainy conditions, the values were within the range of 1.05±0.35 mg/kg - 3.48±0.19 mg/kg. Nevertheless, it's worth noting that these values display significant variability (Table 4), which could be attributed to differences in soil types, land use, or other influencing factors, as suggested by [26].

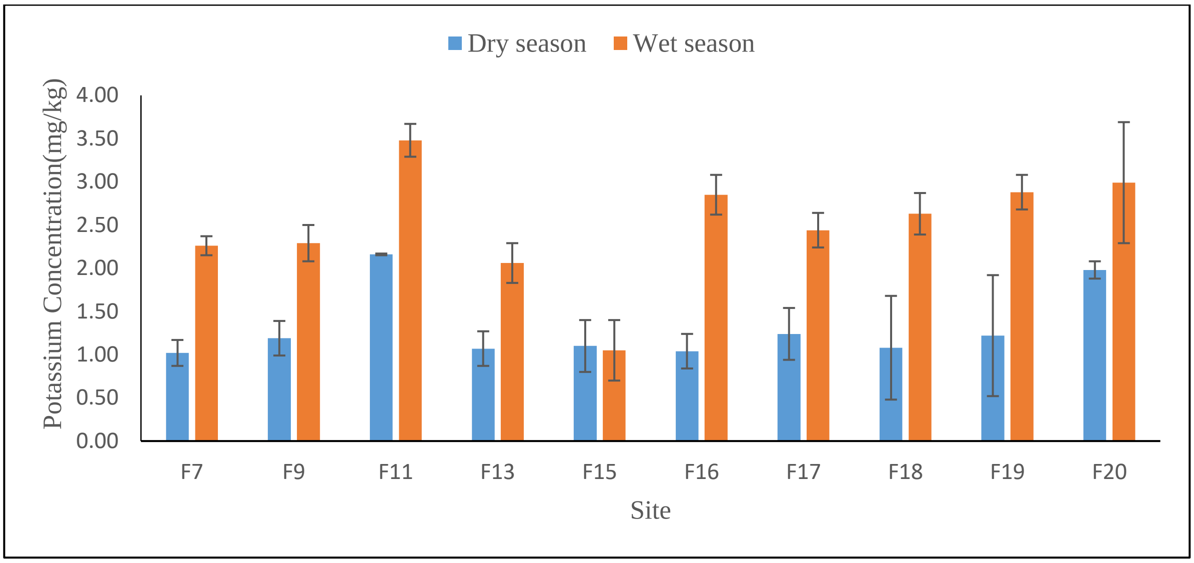

Figure 7: Potassium levels in soil samples in the dry and wet seasons

CONCLUSION AND RECOMMENDATION

Conclusion

The soil physicochemical parameters: pH of soil samples values ranged from 4.07±0.25 - 4.98±0.18 in the seasons. This pH range, indicated a significant degree of acidity, falling below the critical threshold of 5.5, suggesting a probable presence of exchangeable Al^{3+} ions that contributed to lowering the pH of soil by releasing hydrogen ions. The electrical conductivity (EC) ranged from 216 ± 2.70 µS/cm -290 ± 6.30 µS/cm. Site F11 (Thwake Dam area), had the highest value showing the effects of the confluence of Athi and Thwake Rivers with the increased dissolved ions deposited from the runoff water from the entire catchment. The moisture content (MC) levels ranged from 14.19 ± 0.40 % - 38.55 ± 0.42 %. Site F11 had the highest percentage while F16 had the lowest value and this variation may be attributed to differences in topography, vegetation cover and organic materials. The nitrogen nutrients levels in soil samples ranged from 0.15 ± 0.04 - 0.89 ±0.10 mg/kg, while phosphorous was from 0.07 ± 0.03 - 1.50 ± 0.04 mg/kg, whereas potassium values exhibited variations between 1.02 ± 0.15 mg/kg - 3.48 ± 0.19 mg/kg. The levels of the major inorganic nutrients were low in the catchment area, these levels were < 20 <5 and <78 the values set by WHO, for nitrates, phosphate and potassium levels respectively. Nutrients are lost through water run-off, leaching and decomposition to gases. Furthermore, reductions in soil moisture have a notable influence on the absorption of soil nutrients.

Recommendation

The soil acidity in the area is below the critical pH threshold of 5.5, which may indicate high levels of exchangeable Al^{3+} ions. To neutralize this acidity and make nutrients more accessible to plants, liming (application of agricultural lime) is recommended. Additionally, the nitrogen, phosphorus, and potassium levels were below WHO standards, suggesting a need for balanced inorganic fertilizers or organic amendments like compost and manure to improve soil fertility. To prevent further nutrient loss due to water runoff and leaching, soil conservation practices such as contour farming, terracing and cover cropping should be implemented to reduce erosion and retain nutrients in the soil.

DISCLOSURE

The authors declared no conflict of interest.

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REFERENCES

1. Cunningham, G. L. (June 2007) Districts in Kenya. Nairobi Federal Research Division Agricultural Research Division.
2. Kanyanjua, S. M., & Ayega, A. (2006). Soil fertility management in Kenya: A case study of current practices, technologies, and their future potential. In Sustainable Agricultural Practices in Kenya (pp. 45-60). Kenya Agricultural Research Institute (KARI
3. Oseko & Dienya (2015): Oseko, N., & Dienya, H. (2015). Factors influencing the adoption of inorganic fertilizers among smallholder farmers in Kenya. African Journal of Agricultural Research, 10 (3), 200-210.
4. Ruto, J. K., Mutai, B. K., & Langat, J. K. (2019). Comparative analysis of inorganic and organic fertilizer used on maize yield in smallholder farms in Kenya. Journal of Agriculture and Rural Development, 34(2), 120-130.
5. Kibunja, C. N., Mugendi, D. N., & Mucheru-Muna, M. (2017). The influence of organic and inorganic fertilizers on maize yield and soil properties in semi-arid Kenya. Agricultural Research Journal, 45(4), 56-62.
6. Kiboi, M. N., Ngetich, K. F., Fliessbach, A., Muriuki, A., & 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.
7. Marschner, P., & Rengel, Z. (2012). Nutrient availability in soils. In Marschner's mineral nutrition of higher plants (pp. 315-330). Academic Press.
8. Borowik, A., & Wyszkowska, J. (2016). Soil moisture as a factor affecting the microbiological and biochemical activity of soil. Plant, Soil and Environment, 62(6), 250-255.
9. Bhattacharyya, R., Prakash, V., Kundu, S., Srivastva, A. K., & Gupta, H. S. (2017). Long term effects of fertilization on carbon and nitrogen sequestration and aggregate associated C and N status under intensive agriculture. Applied Soil Ecology, 46, 150-158.
10. Liu et al. (2010): Liu, J., Wu, L., Chen, D., Liu, Y., & Wei, C. (2010). Effects of soil pH on growth, yield, and quality of tomato plants. Agricultural Research Journal, 36(3), 189-195
11. Savci, S. (2012). Investigation of effect of chemical fertilizers on environment. Apcbee Procedia, 1, 287-292.
12. Bünemann, E. K., Oberson, A., & Frossard, E. (Eds.). (2010). Phosphorus in action: biological processes in soil phosphorus cycling (Vol. 26). Springer Science & Business Media
13. Carter, M., and Bentley, S. P. (2016). Soil properties and their correlations. John Wiley and Sons.
14. Stein, L. Y., & Klotz, M. G. (2016). The nitrogen cycles. Current Biology, 26(3), R94-R98.
15. Barker, A. V., & Bryson, G. M. (2016). Nitrogen. In Handbook of plant nutrition (pp. 37-66).
16. Boer, T. E., Kleinman, P. J. A., Saporito, L. S., & Allen, A. L. (2019). Phosphorus sorption and desorption in soils amended with poultry litter. Journal of Environmental Quality, 48(2), 378-387.
17. Li, J., Liu, Y., Zhang, W., & Li, Z. (2010). Nutrient accumulation and distribution in soils of agricultural landscapes: A case study in the North China Plain. Journal of Environmental Quality, 39(3), 883-891.
18. Seifu, W., & Elias, E. (2018). Soil quality attributes and their role in sustainable agriculture: a review. International Journal of Plant & Soil Science, 26(3), 1-26.
19. Government of Kenya. Republic of Kenya (2013) Makueni First County Integrated Development Plan. 2017.
20. Alam, S. M., Naqvi, S. S. M., & Ansari, R. A. Z. I. U. D. D. I. N. (1999). Impact of soil pH on nutrient

uptake by crop plants. Handbook of plant and crop stress, 2, 51-60

21. Singare. P, R. Lokhande and P. Pathak (2010) "Soil Pollution along Kalwa Bridge at Thane Creek of Maharashtra, India," Journal of Environmental Protection, Vol. 1 No. 2, pp. 121-128. doi: 10.4236/jep.2010.12016
22. Rhoades, J. D. (1996). Salinity: Electrical conductivity and total dissolved solids. Methods of soil analysis: Part 3 Chemical methods, 5, 417-435
23. Solanki, H. A., & Chavda, N. H. (2012). 12. Physico-chemical analysis with reference to seasonal changes in soils of Victoria Park reserve forest, Bhavnagar (Gujarat) by Ha Solanki and Nh Chavda. Life sciences Leaflets, 30, 62-78.
24. Tale, K. S., & Ingole, S. (2015). A review on role of physico-chemical properties in soil quality. Chemical Science Review and Letters, 4(13), 57-66.
25. Jacobs, S.R, Breuer, L., Butterbach-Bahl, K, Pelster, D.E, and Rufino, M.C. (2017). Land use affects total dissolved nitrogen and nitrate concentration in tropical montane streams in Kenya. Science of the Total Environment, 603, 519-532
26. Ashraf M, Bhat GA, Dar ID, Ali M (2012): Physico-Chemical Characteristics of the Grassland Soils of Yusmarg Hill Resort (Kashmir, India), Eco.Balkanica, 4(1),31-38.