Effects of Catchment Land Use on Water Quality in Maragua and Mathioya Riverine Wetlands, Murang'a County, Kenya

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ABSTRACT

Wetland ecosystems in Murang'a County are diminishing due to increased catchment land use practices. Part of wetlands have been converted into farmlands where various agricultural activities are carried out while some parts have been converted into settlement points. Agricultural practices carried out along wetland ecosystems involve the use of excessive agrochemicals during crop production which later contribute to wetland pollution through nutrients and heavy metals inflows. This study aimed at assessing the effects of catchment land use on water quality parameters in Maragua and Mathioya river basins in Murang'a County. Water samples were collected using the Grab technique, packed in plastic containers, kept in cool boxes, and transported to the research laboratory for analysis. Salinity, turbidity, total dissolved solids (TDS), electrical conductivity (EC) and P^H were analyzed across the sampling levels using hand-held portable pH meter. Salinity mean concentration across the three sampling levels was 116.28 ± 14.31 mg/L; 107.08±13.32 mg/L for TDS; 0.16±0.02 mS/cm for electrical conductivity (EC), turbidity:160.38 ± 8.53 NTU and a P^H mean of 6.26±0.09.

TDS values differed across sampling levels: Down-Stream (mean = 135.43 ± 1.46 mg/L, range: 132.60 to 139.30 mg/L), Mid-Stream (mean = 138.63 ± 6.60 mg/L, range: 122.70 to 150.60 mg/L), and Up-Stream (mean = 47.18 ± 10.43 mg/L, range: 26.70 to 65.40 mg/L). EC showed significant variation across sampling levels: Down-Stream (mean = 0.20 ± 0.00 mS/cm, range: 0.19 to 0.20 mS/cm), Mid-Stream (mean = 0.21 ± 0.01 mS/cm, range: 0.19 to 0.23 mS/cm), and Up-Stream (mean = 0.07 ± 0.02 mS/cm, range: 0.04 to 0.10 mS/cm). The pH levels varied across the different sampling levels: Down-Stream (mean = 6.47 ± 0.03, range: 6.40 to 6.51), Mid-stream (mean = 6.31 ± 0.10, range: 6.01 to 6.45), and Up-Stream (mean = 6.00 ± 0.22, range: 5.50 to 6.48). Salinity levels varied significantly: Down-Stream (mean = 146.05 ± 1.81 mg/L, range: 141.40 to 150.20 mg/L), Mid-Stream (mean = 150.93 ± 6.15 mg/L, range: 135.00 to 161.60 mg/L), and Up-Stream (mean = 51.88 ± 11.52 mg/L, range: 28.90 to 71.70 mg/L) and Turbidity levels also varied: Down-Stream (mean = 170.50 ± 15.40 NTU, range: 128.30 to 194.60 NTU), Mid-Stream (mean = 173.53 ± 8.13 NTU, range: 158.40 to 190.90 NTU), and Up-Stream (mean = 137.10 ± 15.00 NTU, range: 108.20 to 177.50 NTU).

Post-hoc analysis showed a significant difference in pH between Down-Stream and Up-Stream (mean difference = 0.465, $p = .043$). Significant differences noted in EC between Down-Stream and Up-Stream (mean difference = 0.130, $p < .001$), and Mid-Stream and Up-Stream (mean difference = 0.139, $p < .001$). However, no significant difference was observed between Down-Stream and Mid-Stream. For TDS, significant differences were observed between Down-Stream and Up-Stream (mean difference = 88.250, $p < .001$), and Mid-Stream and Up-Stream (mean difference = 91.450, $p < .001$). No significant difference was observed between Down-Stream and Mid-stream. Significant differences in salinity were found between Down-Stream

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and Up-Stream (mean difference = 94.175, $p < .001$), and Mid-Stream and Up-Stream (mean difference = 99.050, $p < .001$). No significant difference was found between Down-Stream and Mid-stream. Variation in the analyzed water parameters across the sampling levels showed that the wetlands have been polluted and the potential sources of pollution are agricultural run-offs and anthropogenic activities.

Key Words: Wetland, Water Quality, Agrochemical, Pollution, Salinity, Turbidity

INTRODUCTION

Wetland ecosystems are the most essential environmental components and accounts for about a third of all the terrestrial primary production. Wetlands are home to approximately seventy percent of the world's biodiversity and are essential for minerals, food and drinking water (Junk *et al*., 2013). Various land use practices have contributed to the influence of the local ecosystems, soil and water quality. Changes in land use systems in Murang'a County, has led to interference of water quality parameters within the wetland ecosystems and subsequently affecting essential roles of wetlands which include: provision of food, drinking water, nutrient conservation, flood control, and groundwater recharge (Abillah *et al*., 2021; Mwangi, 2021). Decline in the size of wetlands have been noticed globally, owing to conversion of wetlands into settlement points, growth of urban centers as well as industrialization purposes (Mitsch & Gosselink, 2015).

Varied catchment land use systems, for instance, agricultural activities, have contributed to pollution of riverine wetland ecosystems (Abillah *et al*., 2021). Massive application of agrochemicals during crop production along the small wetland ecosystems has resulted to rise in nutrients and elemental residue inflows which interferes with the quality of water (Rey-Romero & Oviedo-Ocana., 2022; Zhang *et al*., 2023); and damage to both aquatic and terrestrial organisms dependent on such wetlands (Harms *et al*., 2019; Wagner *et al*., 2008).

This study seeks to ascertain the extent to which various land use practices affect wetland water quality parameters and test on the status of salinity, pH, total dissolved solids (TDS), electrical conductivity (EC) and turbidity of the water samples from Maragua and Mathioya wetland ecosystems in Murang'a County, Kenya. The findings from this research will help in policy formulation aimed at pollution control on wetlands and securing wetland ecosystem services.

MATERIALS AND METHODS

Study Area

Maragua and Mathioya River Basins (Fig. 2.1). are both found in Murang'a County, Kenya. Maragua River Basin is a small riverine wetland ecosystem located in Murang'a South Sub-County in Murang'a County, Kenya. It's near Maragua town, at a longitude of 36.97˚E, latitude 0.77˚S, and an altitude of 1600 m above the sea level. Mathioya River basin is found in Mathioya Sub-County and borders Nyeri County to the North, Kangema Sub-County to the North, Murang'a East Sub-County to the East, and Nyandarua County to the West.

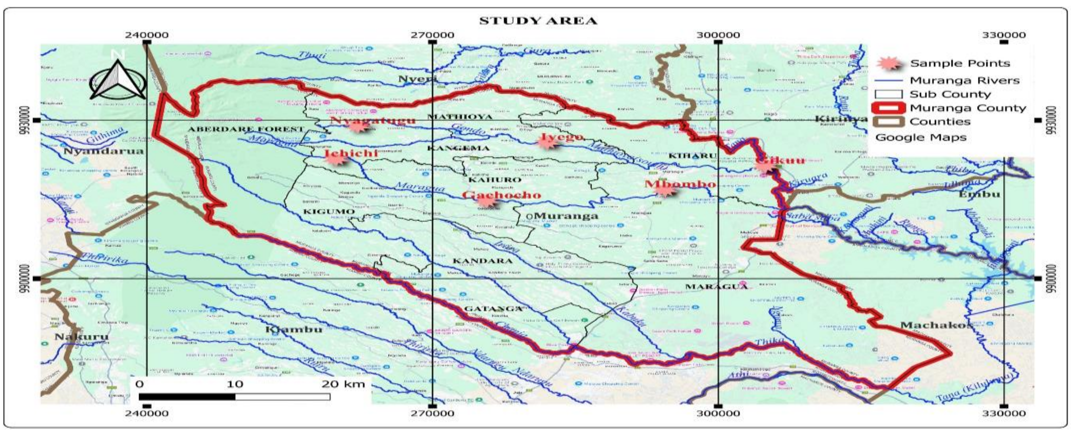

Fig. 2.1 Study Area Map

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Murang'a County's leading economic activity is farming favored by deep red volcanic soils (Fairburn, 1966). The lower regions of the County are underlaid with basement rocks while the upper regions bordering the Aberdare mountains consist of volcanic rocks (Fairburn, 1966). According to the Kenya National Bureau of Statistics, the County's population in 2019 was 1,056,640 (KPHC, 2019). The study area experiences bimodal annual rainfall with long rains falling between March and May and the short rains between October and December. The study area is rich in small, marshy riverine wetland ecosystems.

Collection of Water Samples

Water sampling was carried out in two seasons, that is, dry and wet seasons where a total of 48 samples were analyzed across the three sampling levels, the upstream, mid-stream and downstream in both Maragua and Mathioya river basins. Decision on the sampling points was arrived at with consideration of varied degrees of catchment land use practices as we progress downstream. In Mathioya wetland, samples were collected from Nyagatugu, Iyego and Gikuu sampling points while in Maragua, samples were collected from Ichichi, Gachocho and Mbombo. Nyagatugu and Ichichi represented the upstream sampling level, Iyego and Gachocho represented the mid-stream while Gikuu and Mbombo were the downstream sampling levels. Samples were put in a litre plastic container, labeled, kept in ice boxes, and transported to the laboratory for analysis.

Analysis of Water Samples

Water physico-chemical parameters, that is, **s**alinity, total dissolved solids (TDS), electrical conductivity (EC), turbidity, and P^H were measured using hand-held portable water quality monitor meter (Akerblom,1995) Data were pre-processed, coded, and entered into a spreadsheet for analysis using descriptive and inferential statistics with SPSS software (Garth, 2008).

Quality Protocols and Calibration Routines

Specific quality control (QC) and calibration routines were followed in each parameter analysis to ascertain accuracy, reliability of data and precision of the analytical results. These quality protocols help detect chances or levels of contamination, equipment drift, as well as procedural errors. Both sample duplicates and replicate analyses were performed. **Sample duplicates:** were conducted to assess precision of the analysis where differences between duplicates would indicate variability. **Replicate Analyses:** Involved multiple measurements on the same sample to assess method repeatability. Also, use of blanks, maintenance and cleaning of instruments were observed to ensure quality control. Regular calibration of the instruments was done using specific certified standards for each analysis as shown on summary table 2.1.

Table 2.1. Summary on Quality Control measures and Calibration routines

Parameter	Calibration Frequency	Standard Types	Quality Control (QC) Measures
pH	Daily / per batch	pH 4, 7, 10 buffers	Midpoint check, duplicates, blanks
EC	Daily	EC standards (e.g.1413 µS/cm)	QC standard check, blanks, duplicates
TDS	Indirect via EC	TDS or EC standards	TDS check, replicates, conversion factor check
Turbidity	Daily	Formazin standards	Mid-range check, blanks, replicates
Salinity	Daily	Salinity standards	QC standard check, duplicates

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RESULTS AND DISCUSSION

Water Quality Parameters in Murang'a Wetlands

Analysis was done to determine how various land use systems influence the water quality parameters. Five indicators (pH, EC, salinity, TDS, and turbidity) to water quality were analyzed and results are presented in Table 3.1 for wet and dry season analysis.

Table 3.1. Water Quality Parameters in Murang'a Wetlands for Wet and Dry Seasons

Wetland	**Sampling Level**	**Salinity (mg/L)**		**TDS (mg/L)**		**EC (mS/cm)**		**pH**		**Turbidity (NTU)**	
		Wet	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**
Maragua	**Upstream**	71.7	71.7	64.9	65.4	0.098	0.096	5.50	5.81	177.5	140.5
	Midstream	161.6	159.6	150.6	148.3	0.228	0.219	6.01	6.37	183.8	158.4
	Downstream	141.4	150.2	139.3	135.9	0.199	0.203	6.40	6.45	128.3	166.9
Mathioya	**Upstream**	35.2	28.9	31.7	26.7	0.045	0.039	6.22	6.48	108.2	122.2
	Midstream	135.0	147.5	122.7	132.9	0.187	0.199	6.42	6.45	190.9	161.0
	Downstream	146.0	146.6	133.9	132.6	0.202	0.194	6.51	6.51	194.6	192.2

The water quality parameters varied across the sampling levels as shown in Table 3.1. This is attributed to intensive agricultural practices downstream along the riverine wetland ecosystems which involves massive application of inorganic fertilizers of which through runoff, gets deposited in the water body as residue inflows. Such fertilizers contribute dissolved salts (ions) that facilitate electrical conductivity of the water. Also, some agrochemicals such as lime (alkaline), phosphatic and nitrogenous fertilizers are acidic in nature thus influencing water p^H. Siltation in riverine wetlands contribute to variation in turbidity of the water.

Descriptive Statistics for Water Quality Parameters

pH

The analysis of pH levels across the twelve samples revealed a range from 5.50 to 6.51. The average pH is 6.26 ± 0.09, indicating slightly acidic conditions within the wetland ecosystem. This pH value on tested samples is below the WHO recommended highest desirable level of p^H range of 7-8 (WHO, 2022). This slight acidity could be attributed to natural organic matter decomposition or potential agricultural runoff containing acidic substances, for instance the phosphate fertilizer inflows from inorganic fertilizers. This suggests that farmers should be sensitized on the effects of inorganic fertilizers on water P^H in order to maintain optimum pH levels on wetland waters. The standard deviation of 0.32 suggests that while there is some variation in pH levels, most values are relatively close to the mean. The skewness value of -1.57 ± 0.64 indicates a left-skewed distribution, meaning that there are more pH values below the mean, which pulls the mean towards the lower end (Table 3.2). The kurtosis of 1.68 ± 1.23 shows a leptokurtic distribution, suggesting that the pH data have more extreme values than a normal distribution, which may point to periodic influxes of acidic substances or other environmental factors impacting pH levels sporadically.

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Electrical Conductivity (EC)

Electrical Conductivity (EC) is an important measure of water's ability to conduct electricity, which correlates with the concentration of dissolved salts. The EC values across the twelve samples ranged from 0.04 to 0.23 mS/cm, with a mean value of 0.16 ± 0.02 mS/cm. This indicates a moderate level of salinity in the wetland water, which could be influenced by agricultural runoff or other anthropogenic activities. The standard deviation of 0.07 suggests a moderate level of variability in EC values. The skewness of -0.93 ± 0.64 indicates a left-skewed distribution, suggesting that most EC values are clustered at the higher end of the range. The kurtosis value of -0.87 ± 1.23 indicates a platykurtic distribution, which means the EC values are more evenly spread out with fewer extreme values than would be expected in a normal distribution.

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) are a measure of all organic and inorganic substances dissolved in water. The TDS values in the samples ranged from 26.70 to 150.60 mg/L, with an average of 107.08 ± 13.32 mg/L (Table 3.2) which is below the WHO set highest desirable level of 500 mg/L for drinking water. The TDS value obtained, suggests significant levels of dissolved substances, possibly from soil erosion, agricultural runoff, or organic matter decomposition. The standard deviation of 46.12 indicates substantial variability in TDS levels across the samples, which could reflect changes in land use, weather patterns, or other environmental factors. The skewness of -0.92 ± 0.64 suggests a left-skewed distribution, where higher TDS values are more common, potentially indicating consistent sources of dissolved solids. The kurtosis of -0.90 ± 1.23 further suggests a platykurtic distribution, meaning the TDS values are more evenly spread with fewer extreme values compared to a normal distribution.

Salinity

Salinity measures the salt concentration in water, a crucial parameter for understanding the water's chemical properties. The salinity in the samples ranged from 28.90 to 161.60 mg/L, with a mean value of 116.28 ± 14.31 mg/L. TDS analysis is generally considered a more accurate measure of salinity since salts readily dissolves in water, thus contributing to the dissolved solids. The World Health Organization (WHO) does not have a specific guideline value for maximum salinity in drinking water based on health considerations. However, they do note that taste and acceptability are generally reported as unsatisfactory at levels above 200 mg/L. Some sources suggest a general guide of less than 1,000 mg/L (1.6 dS/m EC) for taste considerations. This relatively high mean salinity could indicate significant contributions from agricultural runoff, which often contains inorganic fertilizers and other salts (Table 3.2). The standard deviation of 49.57 shows considerable variability in salinity levels, reflecting the dynamic nature of the wetland's exposure to different sources of salinity. The skewness of -0.95 ± 0.64 suggests a left-skewed distribution, meaning most of the salinity values are at the higher end, possibly due to frequent inputs of saline water. The kurtosis of -0.86 ± 1.23 suggests a platykurtic distribution, indicating a broader spread of values with fewer extreme high or low values than a normal distribution. Environmental awareness is therefore recommended to enlighten farmers on contribution of catchment land use systems to salinity on wetland waters and also let them understand health effects associated to high salinity in drinking water.

Turbidity

Turbidity measures the cloudiness or haziness of water, indicating the presence of suspended particles such as silt, clay, and organic matter. The turbidity values of the analyzed samples ranged from 108.20 to 194.60 NTU, with a mean of 160.38 ± 8.53 NTU. This surpasses the WHO maximum level permissible of 5 NTU for drinking water (WHO, 2022). This high mean turbidity suggests significant particulate matter in the water, possibly from runoff, erosion, or decaying organic material. The standard deviation of 29.55 indicates considerable variability in turbidity, which might be due to fluctuating environmental conditions such as rainfall or human activities affecting sediment levels. The skewness of -0.51 ± 0.64 indicates a slight left-skewed distribution, with most turbidity values being higher, reflecting the frequent presence of suspended particles. The kurtosis of -1.06 ± 1.23 indicates a platykurtic distribution, showing that the turbidity values are more evenly distributed and less peaked than a normal distribution. From these findings it is suggested that

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farmers should be taken through environmental awareness programme for sensitization on upholding environmental conservation measures in order to keep wetland water quality and control health hazards from water pollution.

Table 3.2: Descriptive Statistics for Water Quality parameters

Descriptive Statistics										
	N	Minimum	Maximum	Mean		Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Std. Error
pH	12	5.50	6.51	6.2608	.09322	.32293	-1.571	.637	1.677	1.232
EC	12	.04	.23	.1591	.01993	.06905	-.927	.637	-.866	1.232
TDS	12	26.70	150.60	107.0750	13.31509	46.12483	-.920	.637	-.904	1.232
Salinity	12	28.90	161.60	116.2833	14.30824	49.56520	-.947	.637	-.859	1.232
Turbidity	12	108.20	194.60	160.3750	8.53167	29.55458	-.505	.637	-1.058	1.232
Valid N (listwise)	12									

Analysis of Variance (ANOVA) of water quality parameters

ANOVA on water quality parameters was done in consideration of the season, sampling points, and sampling levels.

ANOVA for water quality parameters by season

The one-way ANOVA results for pH show a between-group sum of squares of 0.085 with 1 degree of freedom (df), leading to a mean square of 0.085. The within-group sum of squares is 1.062 with 10 df, resulting in a mean square of 0.106. The F-value is 0.800 with a significance level (p-value) of 0.392 (Table 3.3). This indicates that there is no statistically significant difference in pH levels between the dry and wet seasons.

For EC, the between-group sum of squares is 0.000 with 1 df, and the within-group sum of squares is 0.052 with 10 df. The mean squares are both 0.000 and 0.005, respectively, resulting in an F-value of 0.001 and a p-value of 0.972. This suggests no significant difference in EC levels between the seasons. The ANOVA for TDS shows a between-group sum of squares of 0.141 with 1 df, and a within-group sum of squares of 23402.362 with 10 df. The mean squares are 0.141 and 2340.236, respectively (Table 3.3). The F-value is 0.000 with a p-value of 0.994, indicating no significant seasonal difference in TDS levels. For salinity, the between-group sum of squares is 15.413 with 1 df, and the within-group sum of squares is 27008.383 with 10 df. The mean squares are 15.413 and 2700.838, resulting in an F-value of 0.006 and a p-value of 0.941. This means there is no significant difference in salinity between the seasons.

The ANOVA for turbidity shows a between-group sum of squares of 147.701 with 1 df, and a within-group sum of squares of 9460.502 with 10 df. The mean squares are 147.701 and 946.050, respectively. The F-value is 0.156 with a p-value of 0.701, indicating no significant seasonal difference in turbidity levels.

Table 3.3: ANOVA on Water Quality Parameters by Seasons

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	.085	1	.085	.800	.392
	Within Groups	1.062	10	.106		
	Total	1.147	11			
EC	Between Groups	.000	1	.000	.001	.972
	Within Groups	.052	10	.005		
	Total	.052	11			
TDS	Between Groups	.141	1	.141	.000	.994
	Within Groups	23402.362	10	2340.236		
	Total	23402.503	11			
Salinity	Between Groups	15.413	1	15.413	.006	.941
	Within Groups	27008.383	10	2700.838		
	Total	27023.797	11			
Turbidity	Between Groups	147.701	1	147.701	.156	.701
	Within Groups	9460.502	10	946.050		
	Total	9608.202	11			

ANOVA for Water Quality Parameters by Sampling Stations

The one-way ANOVA results for pH show a between-group sum of squares of 0.350 with 1 degree of freedom (df), leading to a mean square of 0.350. The within-group sum of squares is 0.797 with 10 df, resulting in a mean square of 0.080. The F-value is 4.395 with a significance level (p-value) of 0.062. This suggests a marginally non-significant difference in pH levels between the Maragua and Mathioya stations.

For EC, the between-group sum of squares is 0.003 with 1 df, and the within-group sum of squares is 0.050 with 10 df. The mean squares are 0.003 and 0.005, respectively, resulting in an F-value of 0.524 and a p-value of 0.486 (Table 3.4). This indicates no significant difference in EC levels between the Maragua and Mathioya stations. The ANOVA for TDS shows a between-group sum of squares of 1279.267 with 1 df, and a within-group sum of squares of 22123.235 with 10 df. The mean squares are 1279.267 and 2212.324, respectively. The F-value is 0.578 with a p-value of 0.465, indicating no significant difference in TDS levels between the two stations.

For salinity, the between-group sum of squares is 1140.750 with 1 df, and the within-group sum of squares is 25883.047 with 10 df. The mean squares are 1140.750 and 2588.305, resulting in an F-value of 0.441 and a p-value of 0.522. This means there is no significant difference in salinity levels between Maragua and Mathioya (Table 3.4). The ANOVA for turbidity shows a between-group sum of squares of 15.641 with 1 df, and a within-group sum of squares of 9592.562 with 10 df. The mean squares are 15.641 and 959.256, respectively. The F-value is 0.016 with a p-value of 0.901, indicating no significant difference in turbidity levels between the two stations.

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Table 3.4: ANOVA on Water Quality Parameters by Stations

ANOVA by sampling stations						
		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	.350	1	.350	4.395	.062
	Within Groups	.797	10	.080		
	Total	1.147	11			
EC	Between Groups	.003	1	.003	.524	.486
	Within Groups	.050	10	.005		
	Total	.052	11			
TDS	Between Groups	1279.267	1	1279.267	.578	.465
	Within Groups	22123.235	10	2212.324		
	Total	23402.503	11			
Salinity	Between Groups	1140.750	1	1140.750	.441	.522
	Within Groups	25883.047	10	2588.305		
	Total	27023.797	11			
Turbidity	Between Groups	15.641	1	15.641	.016	.901
	Within Groups	9592.562	10	959.256		
	Total	9608.202	11			

ANOVA Analysis of water quality parameters by sampling levels

Table 3.5 presents Analysis of Variance (ANOVA) results of water quality parameters by sampling levels, that is, downstream, midstream and upstream levels. The ANOVA results for pH indicated a between-groups sum of squares of 0.448 with 2 degrees of freedom (df), leading to a mean square of 0.224. The within-groups sum of squares was 0.699 with 9 df, resulting in a mean square of 0.078. The F-value was 2.889 with a significance level (p) of 0.107. Although there was some variation in pH levels across sampling levels, it was not statistically significant, $F(2, 9) = 2.889$, $p = .107$.

The ANOVA for EC showed a between-groups sum of squares of 0.048 with 2 df, and the within-groups sum of squares was 0.004 with 9 df. The mean squares were 0.024 and 0.000, respectively, resulting in an F-value of 52.546 and a p-value of less than 0.001. This indicates a highly significant difference in EC levels between the sampling levels, $F(2, 9) = 52.546$, $p < .001$.

For TDS, the ANOVA results showed a between-groups sum of squares of 21,548.540 with 2 df, and a within-groups sum of squares of 1,853.963 with 9 df. The mean squares were 10,774.270 and 205.996, respectively. The F-value was 52.303 with a p-value of less than 0.001, indicating a highly significant difference in TDS levels between the sampling levels, $F(2, 9) = 52.303$, $p < .001$ (Table 3.5).

The ANOVA for salinity revealed a between-groups sum of squares of 24,938.132 with 2 df, and a within-groups sum of squares of 2,085.665 with 9 df. The mean squares were 12,469.066 and 231.741, respectively. The F-value was 53.806 with a p-value of less than 0.001, indicating a highly significant difference in salinity levels between the sampling levels, $F(2, 9) = 53.806$, $p < .001$.

For turbidity, the ANOVA results showed a between-groups sum of squares of 3,268.655 with 2 df, and a within-groups sum of squares of 6,339.548 with 9 df. The mean squares were 1,634.328 and 704.394, respectively (Table 3.5). The F-value was 2.320 with a p-value of 0.154, indicating no significant difference in turbidity levels between the sampling levels, $F(2, 9) = 2.320$, $p = .154$.

Table 3.5: ANOVA on water quality parameters by sampling levels

ANOVA by sampling levels						
		Sum of Squares	Df	Mean Square	F	Sig.
pH	Between Groups	.448	2	.224	2.889	.107
	Within Groups	.699	9	.078		
	Total	1.147	11			
EC	Between Groups	.048	2	.024	52.546	.000
	Within Groups	.004	9	.000		
	Total	.052	11			
TDS	Between Groups	21548.540	2	10774.270	52.303	.000
	Within Groups	1853.963	9	205.996		
	Total	23402.503	11			
Salinity	Between Groups	24938.132	2	12469.066	53.806	.000
	Within Groups	2085.665	9	231.741		
	Total	27023.797	11			
Turbidity	Between Groups	3268.655	2	1634.328	2.320	.154
	Within Groups	6339.548	9	704.394		
	Total	9608.203	11			

Post-Hoc Test for the ANOVA by sampling levels

The post-hoc test indicated a significant difference in pH between Down-Stream and Up-Stream (mean difference = 0.465, $p = .043$). No significant differences were found between Down-Stream and Mid-stream, or Mid-stream and Up-Stream (Table 3.6). Significant differences in EC were observed between Down-Stream and Up-Stream (mean difference = 0.130, $p < .001$), and Mid-Stream and Up-Stream (mean difference = 0.139, $p < .001$). However, no significant difference was observed between Down-Stream and Mid-stream.

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Significant differences in TDS were observed between Down-Stream and Up-Stream (mean difference = 88.250, p < .001), and Mid-Stream and Up-Stream (mean difference = 91.450, p < .001). No significant difference was observed between Down-Stream and Mid-stream.

Significant differences in salinity were found between Down-Stream and Up-Stream (mean difference = 94.175, p < .001), and Mid-Stream and Up-Stream (mean difference = 99.050, p < .001). No significant difference was found between Down-Stream and Mid-stream. No significant differences in turbidity were found between any of the sampling levels (Table 3.6).

Table 3.6: LSD on water quality parameters at various sampling levels

Multiple Comparisons							
LSD							
Dependent Variable	(I) Sampling level	(J) Sampling level	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Ph	Down-Stream	Mid-stream	.15500	.19701	.452	-.2907	.6007
		Up-Stream	.46500*	.19701	.043	.0193	.9107
	Mid-stream	Down-Stream	-.15500	.19701	.452	-.6007	.2907
		Up-Stream	.31000	.19701	.150	-.1357	.7557
	Up-Stream	Down-Stream	-.46500*	.19701	.043	-.9107	-.0193
		Mid-stream	-.31000	.19701	.150	-.7557	.1357
EC	Down-Stream	Mid-stream	-.00875	.01516	.578	-.0430	.0255
		Up-Stream	.13000*	.01516	.000	.0957	.1643
	Mid-stream	Down-Stream	.00875	.01516	.578	-.0255	.0430
		Up-Stream	.13875*	.01516	.000	.1045	.1730
	Up-Stream	Down-Stream	-.13000*	.01516	.000	-.1643	-.0957
		Mid-stream	-.13875*	.01516	.000	-.1730	-.1045
TDS	Down-Stream	Mid-stream	-3.20000	10.14879	.760	-26.1582	19.7582
		Up-Stream	88.25000*	10.14879	.000	65.2918	111.2082
	Mid-stream	Down-Stream	3.20000	10.14879	.760	-19.7582	26.1582

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		Up-Stream	91.45000*	10.14879	.000	68.4918	114.4082
	Up-Stream	Down-Stream	-88.25000*	10.14879	.000	-111.2082	-65.2918
		Mid-stream	-91.45000*	10.14879	.000	-114.4082	-68.4918
Salinity	Down-Stream	Mid-stream	-4.87500	10.76431	.661	-29.2256	19.4756
		Up-Stream	94.17500*	10.76431	.000	69.8244	118.5256
	Mid-stream	Down-Stream	4.87500	10.76431	.661	-19.4756	29.2256
		Up-Stream	99.05000*	10.76431	.000	74.6994	123.4006
	Up-Stream	Down-Stream	-94.17500*	10.76431	.000	-118.5256	-69.8244
		Mid-stream	-99.05000*	10.76431	.000	-123.4006	-74.6994
Turbidity	Down-Stream	Mid-stream	-3.02500	18.76691	.876	-45.4787	39.4287
		Up-Stream	33.40000	18.76691	.109	-9.0537	75.8537
	Mid-stream	Down-Stream	3.02500	18.76691	.876	-39.4287	45.4787
		Up-Stream	36.42500	18.76691	.084	-6.0287	78.8787
	Up-Stream	Down-Stream	-33.40000	18.76691	.109	-75.8537	9.0537
		Mid-stream	-36.42500	18.76691	.084	-78.8787	6.0287
*. The mean difference is significant at the 0.05 level.							

In summary, the descriptive statistics and ANOVA results for pH, EC, TDS, salinity, and turbidity reveal significant differences in EC, TDS, and salinity across the sampling levels (Down-Stream, Mid-stream, and Up-Stream). pH shows marginal variation, while turbidity differences are not statistically significant. The post-hoc analysis further clarifies the significant differences, especially highlighting substantial discrepancies between the Down-Stream and Up-Stream, and Mid-stream and Up-Stream levels in EC, TDS, and salinity. These findings suggest that water quality parameters are significantly affected by the location along the stream, with upstream areas showing lower values for most parameters compared to mid-stream and downstream areas.

CONCLUSIONS

The study on the effects of catchment land use on water quality in the Maragua and Mathioya riverine wetlands in Murang'a County, Kenya, reveals significant impacts of anthropogenic activities, particularly agricultural practices, on wetland water quality. The analysis of water quality parameters pH, electrical conductivity (EC), total dissolved solids (TDS), salinity, and turbidity demonstrates notable variations across sampling levels (upstream, midstream, and downstream). Upstream areas exhibited lower values for EC, TDS, and salinity compared to midstream and downstream, where intensive agricultural activities and agrochemical use contribute to elevated levels of dissolved salts and solids through runoff. The slightly acidic pH (mean 6.26

± 0.09) suggests influences from organic matter decomposition and acidic agricultural inputs, such as phosphate fertilizers. While turbidity showed high variability (mean 160.38 ± 8.53 NTU), no significant differences were observed across sampling levels, likely due to consistent sediment inputs from erosion and runoff across the wetlands. ANOVA and post-hoc analyses confirmed significant differences in EC, TDS, and salinity between upstream and both midstream and downstream levels, underscoring the cumulative impact of land use practices as water flows through the catchment. These findings highlight the need for stringent monitoring and policy interventions to regulate agrochemical use and land conversion practices to preserve wetland ecosystem services, ensure water safety for dependent organisms and humans, and mitigate pollution-related health and environmental risks.

Conflict of interest

The authors of this study wish to confirm that they have no conflict of interest. The funding sponsors had no intervention in the study design and the choice to publish the results.

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