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CHEMICAL CHARACTERISTICS OF THREE ERODED SITES AT YELWAN TUDU, BAUCHI, NIGERIA: A COMPARATIVE APPROACH

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Abstract: The concentrations of trace metals (mg/kg) in three eroded environments (A, B, C) and a control site (U) in Yelwan Tudu Bauchi, Bauchi State Nigeria were analyzed. The levels of metals, including Na, Ca, Mg, K, N, P Mg, Fe, Mn, Cu, Zn in both eroded and uneroded soil Samples were measured using Atomic Absorption Spectrophotometry.
The soil samples were obtained at a depth of 0-30 cm and were thoroughly homogenized to obtain a composite sample for each site and was analyzed using standard procedure. Significant differences in metal concentrations were found across the sites A, B, C and control site, as shown by one-way ANOVA and least significant difference (LSD) tests.

Keywords: Metals, Atomic Absorption Spectroscopy, Analysis of Variance (ANOVA), Least Significant Difference (LSD), Eroded and Uneroded soil Sample.

1.0 INTRODUCTION

1.1 Background of the Study

Soil can be defined as the organic and inorganic material on the earth's surface resulting from the interaction between atmospheric agents and biological activity in the original material or in the underlying hard rock (Berk,2008). Soil provides a physical medium for plant growth. Since the soil supplies nutrients, water, air, and anchoring and is compatible with life on earth, it can be calling Infinite Life Soul (Mehraj et al., 2019).
Soil according to Kingyang (2007) is define as collection of natural bodies on the earth surface supporting plant with lower limit at the depth of either unconsolidated minerals or organic materials lying within the rooting zone of plant. Soil is a natural body of loose unconsolidated dilated materials, which constitute a thin layer several meters deep on the earth surface. It is derived from weathered parent materials and decaying organic matter and is composed of soil particles with liquid or grasses occupying the space between the particles (Kefas et al., 2006).
Soil erosion is a naturally occurring process and it is a normal geological phenomenon associated with the hydrologic cycle. It is a gradual process, which occurs when the impact of water detaches and removes soil particles causing the soil to deteriorate (Jazouli et al., 2017).
Soil is an anchor for plant roots and as a water-holding reservoir for needed moisture; soil delivers a hospitable place for a plant to take root (Christopher et al., 2017). Some of the soil properties affecting plant growth include soil texture (coarse or fine), aggregate size, porosity, aeration (permeability), and water holding capacity. Soil erosion is one form of soil degradation along with soil compaction, low organic matter, and loss of soil structure,

poor internal drainage, salinization, and soil acidity problems. These other forms of soil degradation, serious in themselves, usually contribute to accelerated soil erosion (Jan 2017).

According to Ewetol and Oshunsanya (2015), erosion by water is a major cause of soil degradation in the humid tropics. Damages from water erosion include the physical loss of topsoil materials with its constituent's nutrients, exposure of less fertile subsoil, loss of organic matter, reduction in root depth, reduction of soil available water holding capacity, reduction of soil structural stability, surface sealing, and reduced infiltration rate.

Soil erosion in catchment areas and the subsequent deposition in rivers, lakes, and reservoirs are of great concern for two reasons. Firstly, the rich and fertile soil is eroded in the catchment areas. Secondly, there is a reduction in reservoir capacity as well as degradation of downstream water quality. Soil loss is the result of soil erosion. This, in turn, decreases soil fertility and reduces crop yield. Soil erosion can never be stopped completely, but it can be mitigated to some extent. There is considerable potential for the use of GIS technology as an aid to soil erosion inventory with reference to soil erosion modeling and erosion hazard assessment (Aafaf et al., 2017) Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks.

Salts accumulates naturally in some surface soil of arid and semi-arid region because there is insufficient rainfall to flush them from upper soil layers. The salts are primarily chloride and sulfates of calcium, magnesium, sodium and potassium. They may be formed during the weathering of rocks and minerals brought to the soil through rainfall and irrigation. Other localize but important source is fossils deposit of salt laid down during geological time in the bottom of now extinct lakes or oceans or underground saline water pools. These fossils salt can be dissolved in underground water that move horizontally through varying underlying impervious geological layers and ultimately rise to the surface of soil in the low-lying parts of the landscape, often forming saline seep. The water evaporates leaving salt in place at near the soil surface. Unfortunately, most plants cannot tolerate high level of these salts, a fact that severely limits the use of some salt affected soil (Andrews and Karlen, 2004).

Ekpo, (2021) Erosion, both onsite and offsite, is recognized globally as a significant issue. It is influenced by soil erodibility and rainfall erosivity, with diverse geologic formations leading to varied soil responses during erosive events. In this study, five geologic formations were identified, and soil samples from different depths underwent laboratory analysis. The erodibility indices, determined using the Wischmeier and Smith model based on fine sand, silt, clay, organic matter, and permeability, revealed vulnerability to erosion. Results indicate that Alluvium, Ameki, Benin, Imo, and Ogwashi geologic formations have distinct average K factors, emphasizing the susceptibility of soils in the study area to erosion.

Okay et al. (2017) Gully formation and erosion have emerged as significant environmental challenges in southeastern Nigeria, posing a threat to agriculture, sustainability, and food security. Soil erosion has adversely affected agricultural productivity, limiting farmland availability for both farming and construction activities. This paper reviews the causes and effects of soil erosion in the region, emphasizing control measures such as cultivating vegetative cover, implementing soil and water conservation practices, adopting proper crop management techniques, and engaging in community-based campaigns to mitigate these threats and preserve soil quality.

2.0 MATERIALS AND METHODS

2.1 Materials/ Equipment

All materials of analytical standard were used and the instrument used in the determination of availability of trace metals in the samples was Atomic Absorption Spectrophotometer 210vgp model.

The phosphorus (P), phosphorus-pentoxide (P2O5) and phosphate (PO4) of Soil extract,
Phosphate was determined by using orthophosphate phosVer 3 (Ascorbic Acid) Method 8048 (Powder Pillows) (Standard methods, 1976; DWAF, 1992). USEPA accepted for reporting wastewater analysis by using powder pillows phosver®3phosphate reagent CAT NO. 2106069 with a DR/890 colorimeter of serial no. 130290694066, produced by Hach company world headquarters, Loveland, USA, the procedure was adopted.

2.1.1 Reagents and solutions

Samples prior to elemental analysis the method employ for this study was tri-acid digestion method, in the ratio of 5:1:1, (Nitric acid) HNO3, (Hydrochloric acid) HCL, (Perchloric acid) HCLO4. the soil sample was grounded to powder form using pistil and mortar. 1g was weigh in to 50ml conical flask and 15ml of tri acid ration 5:1:1 ie 5ml of 63.01% HNO3, 1ml of 65-70% HCL and 1ml of 70% HCLO4 acid was added to the sample,
The mixture was heated on a heating mantle at 90OC in the fume cup board until the sample become transparent (Sharma et al., 2009).
The resulting solution was filtered and diluted to 50ml with distilled water and was analyzed for heavy elemental metals using 210vgp (AAS), Atomic Absorption Spectrophotometer.

2.2 Sample Collection and Preparation

2.2.1 Sampling of soil

Substratum soil samples were collected Yelwan Tudu area of Bauchi State from three different eroded environments (of the same region) designated as: Site A, B, C and Control (of different region) at a depth of 1-30 cm and used for the for the determination of different metal concentration. The soil samples were collected in clean polyethylene bags were labeled. The soil obtained from several sites were separately homogenized to form a composite sample which was air- dried, ground and sieved via a mesh (2 mm) and preserved for further chemical analyses.

2.2 .2 Description of the Study Area

This study was carried out in the postgraduate laboratory of the Department of Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria. Bauchi State has a varying climate with a cool dry season (harmattan) from October to February, a hot dry season from March to May and a warm wet season from June to September. Bauchi state is located in the northern part of Nigeria, and it covers 45,837 square kilometers. The state is bordered by Kano and Jigawa States to the North, while Yobe and Gombe to the East, Kaduna to the West and Plateau to the South.

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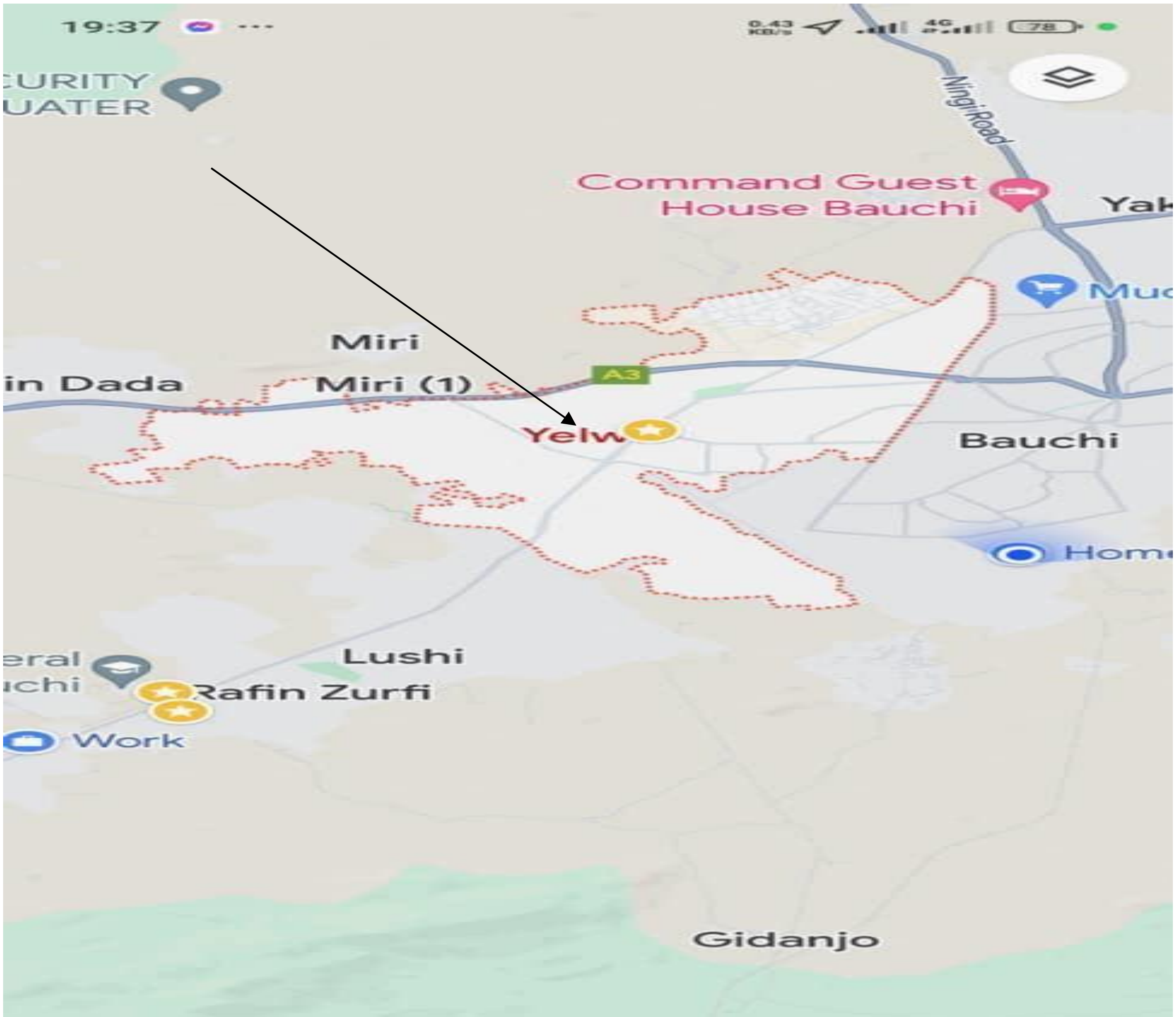

Figure 3.1 Geographical map of Yelwan Tudu Bauchi, Bauchi state Nigeria showing the sampling location

2.3 Determination of soil chemical properties

The parameters determined were total nitrogen, available potassium, available phosphorus, macronutrients and micronutrients was determined. Soil total nitrogen (TN) was determined by Kjeldahl method, available phosphorus (PA) was determined by colorimetric method, available potassium (KA) was determined by the ammonium acetate spectrophotometry method, cation exchange capacity was determined by the neutral ammonium acetate method. Soil macronutrients and micronutrients was determined using the atomic absorption spectrophotometry method.

2.4 Digestion Procedure 2.4. 1. Digestion of soil

A 20.00 g of the soil samples prepared was placed in a pre-weighed 250 cm^3 conical flask. 50.00 cm^3 of 0.10 mol/dm^3 hydrochloric acid was added and agitated by hand for a minute. The mixture was allowed to stand at room temperature for an hour and the manual agitation will again be repeated three more times, will then be filtered through a Whatman filter paper number 1 into a 100 cm³ volumetric flask and water will then be added to volume. This solution was used for the determination of the concentrations of the extractable micronutrients (Cu, Zn, Fe and Mn) in the soil samples before determinations was carried out at their respective wavelengths using the Atomic Absorption Spectrophotometer. (Molindo, 2008).

2.5 Statistical Analysis

The data generated in this analysis are means and standard deviation as evaluated by AAS instrument (AA32ON Shanghai General Analytical Instruments). The data generated for levels of metals in soil samples were subjected to One-way Analysis of Variance (ANOVA) and Least Significant Difference (LSD) to test for variations.

3.0 RESULTS AND DISCUSSION

3.1 Results

3.1.1 Concentration of Exchangeable Bases (cmol/kg) at three different sites

Table 1: Concentration of Exchangeable Bases (cmol/kg) at three different sites A, B and C with Control from Yelwan Tudu Bauchi.

Sample	Na	Ca	Mg	K
Control	$1.81^{a}\pm0.02$	$4.87^{a}\pm0.01$	$4.48^{a}\pm0.08$	$5.50^{a}\pm0.05$
Site A	$6.03^{b}\pm0.32$	$2.30^{b}\pm0.01$	$0.31^{b}\pm0.01$	$4.26^{b}\pm0.05$
Site B	$8.22^{c}\pm0.11$	$3.58^{a}\pm0.88$	$0.33^{b}\pm0.01$	$6.31^{c}\pm0.02$
Site C	$8.37^{d}\pm0.10$	$3.14^{c}\pm0.04$	$0.35^{b}\pm0.01$	$5.95^{d}\pm0.02$

Values are mean ± standard deviation (n= 3). Values on the same row with different superscript letters are significantly different as revealed by one-way ANOVA and least significant difference (LSD) test ($p \leq 0.05$), while those with same superscript letters are significantly the same. The superscript letters a, b, c and d represents level of significance.

Table 1 above presents the concentrations of sodium (Na) at the control site and the three test sites (A, B, and C) were found to be 1.81, 6.03, 8.22, and 8.37 cmol/kg, respectively. According to the Federal Ministry of Agriculture and Rural Development (FMARD), the standard threshold for sodium in agricultural soils is 0.7 cmol/kg, which indicates that all sites have sodium levels exceeding the recommended limit. Site B and C, in particular, have significantly high sodium concentrations (8.22 and 8.37 cmol/kg), far above the control and the standard, highlighting potential soil quality degradation due to sodium accumulation.

The high sodium levels observed at Sites A, B, and C can negatively affect soil structure by causing soil dispersion, as noted by Rowley et al. (2018). This soil dispersion can lead to reduced porosity, water infiltration issues, and poor drainage. The high sodium concentration at Site B suggests that the soil is more susceptible to these effects, further supported by the findings of Warrence et al. (2002) and Shahid et al. (2018), who reported that soils with low salinity but high sodicity could experience severe infiltration problems and increased erosion potential.

In comparison, calcium (Ca) levels at Site A (2.30 cmol/kg), Site B (3.58 cmol/kg), and Site C (3.14 cmol/kg) are all below the FMARD recommended threshold of 6.0 cmol/kg. This deficiency suggests a potential issue with calcium availability, which is critical for maintaining soil structure and overall fertility.

The magnesium (Mg) levels were found to be quite low across the test sites (0.31–0.35 cmol/kg), which is significantly below the FMARD threshold of 2.0 cmol/kg. This indicates a deficiency that could negatively impact plant growth, as magnesium is essential for photosynthesis and plant metabolism.

Potassium (K) concentrations at Sites A and C (4.26 cmol/kg and 5.95 cmol/kg, respectively) are higher than the FMARD threshold of 0.5 cmol/kg, indicating sufficient potassium availability for plants. However, Site B shows

an even higher potassium concentration (6.31 cmol/kg), which may suggest that the soil has adequate potassium reserves but could also indicate potential nutrient imbalance due to the disproportionately high sodium levels.
The findings suggest that the soils in Yelwan Tudu, Bauchi, particularly at Sites B and C, have excessive sodium levels compared to the FMARD standards, which could lead to poor soil structure and impaired crop productivity. Additionally, deficiencies in calcium and magnesium across the sites highlight the need for targeted soil amendments to improve fertility and ensure sustainable agricultural productivity.

3.1.2 Concentration of trace metals (mg/kg) in soil samples

Table 2: Concentrations of Trace Metals (mg/kg) at three different sites A, B and C with Control

Sample	Fe	Mn	Cu	Zn
Control	$4.72^{a}\pm0.07$	$10.44^{a}\pm0.19$	$1.29^{a}\pm1.29$	$22.69^{a}\pm2.18$
Site A	$1.74^{b}\pm1.59$	$8.65^{b}\pm0.18$	$2.26^{b}\pm2.33$	$10.00^{b}\pm7.40$
Site B	$3.98^{a}\pm0.60$	$9.55^{c}\pm0.10$	$3.81^{c}\pm1.45$	$15.58^{c}\pm12.24$
Site C	$3.85^{a}\pm0.43$	$9.99^{d}\pm0.54$	$1.90^{d}\pm1.11$	$23.51^{a}\pm1.36$

Values are mean ± standard deviation (n= 3). Values on the same row with different superscript letters are significantly different as revealed by one-way ANOVA and least significant difference (LSD) test ($p \leq 0.05$), while those with same superscript letters are significantly the same. The superscript letters a, b, c and d represents level of significance.

Table 2 above presents the concentrations of four trace metals (Iron - Fe, Manganese - Mn, Copper - Cu, and Zinc - Zn) at three different sites (A, B, and C) in Yelwan Tudu, Bauchi, compared to a control sample. The findings are also compared with the trace metal standards established by the Federal Ministry of Agriculture and Rural Development (FMARD).

The concentrations of iron ranged from 1.74 mg/kg (Site A) to 4.72 mg/kg (Control). According to FMARD, the recommended threshold for iron in agricultural soils is 10 mg/kg. The iron levels observed across all sites fall significantly below this threshold, indicating an iron deficiency. This deficiency can impair plant functions, as iron is critical for chlorophyll production and photosynthesis. Site A has the lowest iron concentration (1.74 mg/kg), which could be due to erosion or nutrient leaching. Site C (3.85 mg/kg) and Site B (3.98 mg/kg) have moderate iron levels, but they are still inadequate to meet the recommended standard. The control site exhibits the highest iron level (4.72 mg/kg), which suggests that uneroded soils may retain more nutrients. Manganese concentrations ranged from 8.65 mg/kg (Site A) to 10.44 mg/kg (Control). FMARD’s threshold for manganese is 5 mg/kg, meaning all sites exceed this standard, indicating sufficient manganese levels for healthy plant growth. Despite this, Site A has the lowest manganese concentration (8.65 mg/kg), which, while above the standard, may still impact plant enzyme activation and photosynthesis. Site C shows a manganese concentration of 9.99 mg/kg, while Site B has 9.55 mg/kg. Both sides remain well above the critical level but slightly lower than the control (10.44 mg/kg), which maintains the highest manganese levels. This suggests that uneroded soils are better at preserving trace metals such as manganese.

Copper concentrations range from 1.29 mg/kg (Control) to 3.81 mg/kg (Site B). FMARD's guideline for copper concentration is 1 mg/kg, and all sites surpass this threshold, indicating adequate copper availability for plant enzymatic activity. Site B exhibits the highest copper concentration (3.81 mg/kg), which may suggest external inputs like fertilizers. Site A has a copper concentration of 2.26 mg/kg, while Site C measures 1.90 mg/kg. These levels are significantly higher than the control (1.29 mg/kg), where the uneroded soil maintains just above the FMARD standard. Excessive copper, as seen in Site B, could potentially lead to toxicity in sensitive plants, while lower levels in Site A and C are within safe limits.

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Zinc concentrations ranged from 10.00 mg/kg (Site A) to 23.51 mg/kg (Site C), with the control sample at 22.69 mg/kg. The FMARD standard for zinc is 3 mg/kg, and all sites exceed this value, indicating ample zinc availability for plants. Site C exhibits the highest zinc concentration (23.51 mg/kg), suggesting localized high zinc levels that may be the result of natural variation or human activities like the use of fertilizers. Site A shows the lowest zinc concentration (10.00 mg/kg), but this still exceeds the FMARD standard, meaning the soil remains fertile for zinc. The control site also has a high zinc concentration (22.69 mg/kg), indicating that uneroded soils retain adequate levels of this trace metal.

Iron (Fe): All sites show iron deficiency, as the concentrations fall below the 10 mg/kg threshold.

This could negatively affect plant chlorophyll production, potentially hindering growth, Manganese (Mn): The manganese levels at all sites exceed the FMARD standard of 5 mg/kg, indicating adequate manganese for plant development, although Site A shows lower manganese content than the control, Copper (Cu): Copper levels are above the FMARD standard of 1 mg/kg at all sites. While Site B shows a higher copper concentration, it remains within safe levels for plant health, while Site A and Site C have moderate levels and Zinc (Zn): All sites exhibit zinc concentrations that far exceed the FMARD threshold of 3 mg/kg, showing no risk of zinc deficiency. Site A has lower zinc levels than the other sites, but it is still fertile enough for optimal plant growth.

While manganese, copper, and zinc levels are within or above the acceptable ranges for plant growth, iron remains deficient across all sites. This suggests that iron supplementation and better soil management practices may be needed to improve soil fertility and enhance plant productivity in Yelwan Tudu.

3.1.3 Levels of Macronutrients of (mg/kg) at three different sites A, B and C with Control from Yelwan Tudu Bauchi

Table 3: Levels of Macronutrients of (mg/kg) at three different sites A, B and C with Control from Yelwan Tudu Bauchi.

$N0_{3-}$	$P0_{43-}$	N	P	K
$310.97^{a}\pm2.44$	$4.10^{a}\pm0.26$	$70.30^{a}\pm0.5$	$1.3^{a}\pm0.10$	$5.50^{a}\pm0.05$
$343.40^{b}\pm1.85$	$1.4^{b}\pm0.52$	$77.6^{b}\pm0.5$	$0.5^{b}\pm0.2$	$4.26^{b}\pm0.05$
$248.47^{c}\pm1.10$	$10.87^{c}\pm0.12$	$56.17^{c}\pm0.2$	$3.5^{c}\pm0.06$	$6.31^{c}\pm0.02$
$298.63^{d}\pm0.55$	$5.43^{d}\pm0.06$	$67.53^{d}\pm0.1$	$1.8^{d}\pm0.06$	$5.935^{d}\pm0.02$

Values are mean ± standard deviation (n= 3). Values on the same row with different superscript letters are significantly different as revealed by one-way ANOVA and least significant difference (LSD) test ($p \leq 0.05$), while those with same superscript letters are significantly the same. The superscript letters a, b, c and d represents level of significance**.**

Table 3 above presents the levels of macronutrients, including nitrate ($N0_3^-$), phosphate ($P0_4^{3-}$), nitrogen (N), phosphorus (P), and potassium (K), were measured at three different sites (A, B, C) in Yelwan Tudu, Bauchi, and compared with control soil. The results indicate varying nutrient levels across the sites.

The nitrate levels ranged from 248.47 mg/kg (Site B) to 343.40 mg/kg (Site A), with the control site showing 310.97 mg/kg. Nitrate concentration at Site A was significantly higher than the control, which could indicate higher organic matter or fertilizer inputs at this location. In contrast, Site B had the lowest nitrate concentration (248.47 mg/kg), suggesting possible denitrification, erosion, or leaching, which may have reduced nitrate availability. These variations align with erosion patterns, where nitrate levels can be diminished in eroded soils, impacting crop growth.

Phosphate levels ranged from 1.4 mg/kg (Site A) to 10.87 mg/kg (Site B), with the control site showing 4.10 mg/kg. According to FMARD guidelines, soil phosphorus levels should ideally be around 15 mg/kg. All sites fell short of this benchmark, indicating potential phosphorus deficiency, especially at Site A, where phosphate concentration (1.4 mg/kg) was significantly lower than the control. This low phosphorus level highlights the impact of erosion on phosphorus availability, as erosion typically depletes essential nutrients. Site B, however, showed the highest phosphate concentration (10.87 mg/kg), possibly due to localized phosphate accumulation or external inputs. Nitrogen levels ranged from 56.17 mg/kg (Site B) to 77.60 mg/kg (Site A), with the control site showing 70.30 mg/kg. According to FMARD standards, nitrogen content is usually measured indirectly through organic matter content rather than exact mg/kg thresholds. However, Site B had significantly lower nitrogen levels (56.17 mg/kg), indicating a reduction in fertility, likely caused by erosion or nutrient leaching. Site A, on the other hand, had nitrogen levels above the control, indicating better nutrient retention in uneroded areas.

Phosphorus levels ranged from 0.5 mg/kg (Site A) to 3.5 mg/kg (Site B), with the control site at 1.3 mg/kg. Site A had the lowest phosphorus concentration (0.5 mg/kg), which is well below the FMARD-recommended threshold of 15 mg/kg, indicating a serious depletion of phosphorus due to erosion. The low phosphorus concentration affects soil fertility and can impair plant growth, as phosphorus is essential for root development and energy transfer. Site B, however, showed a much higher phosphorus level (3.5 mg/kg), indicating uneven distribution, likely due to varying erosion impacts or external nutrient inputs.

Potassium levels ranged from 4.26 mg/kg (Site A) to 6.31 mg/kg (Site B), with the control site showing 5.50 mg/kg. FMARD's threshold for potassium is 0.5 mg/kg, and all sites significantly exceed this value, indicating adequate potassium availability for plant growth. However, Site B showed the highest potassium concentration (6.31 mg/kg), which might suggest nutrient imbalance due to the high sodium levels observed earlier.

The comparison with FMARD's macronutrient standards reveals nutrient imbalances across the sites, with phosphorus being a notable deficiency. Sites A and B experience the most significant variations, with Site A suffering from lower nutrient levels due to erosion, while Site B exhibits uneven nutrient distribution. Corrective soil management practices, including phosphorus supplementation and erosion control measures, are necessary to improve soil fertility and ensure sustainable agricultural productivity.

3.2 Discussion of findings

Phosphorus (P) levels in soil are crucial for understanding soil fertility and its ability to support plant growth. Comparing phosphorus levels in eroded and uneroded soil samples can provide insights into the impact of soil erosion on soil quality and nutrient availability. Sample A shows a significantly lower phosphorus level (0.5 mg/kg) compared to uneroded soil (1.3 mg/kg). This revealed that erosion has led to a substantial loss of phosphorus in this sample, therefore reducing soil fertility and affecting plant growth. Eroded Sample "A" shows higher variability (SD = 0.20), suggesting inconsistent phosphorus distribution, likely due to the uneven impact of erosion. Thus, indicating that Phosphorus level has depleted in eroded soil sample.

Sample B exhibits a much higher phosphorus level (3.5 mg/kg) than the uneroded soil (1.3 mg/kg) this shows uneven distribution of phosphorus within the study area, where certain spots exhibit higher levels of phosphorus compared to the surrounding soil.

This could indicate that in certain areas, eroded soil has accumulated phosphorus, possibly due to the deposition of nutrient-rich sediments. Areas with high phosphorus levels can support robust plant growth, but this imbalance can lead to uneven crop yields across a field and potential runoff issues.

Sample C has a phosphorus level (1.8 mg/kg) higher than the uneroded soil but not as high as Sample B. This suggests moderate erosion impact, where some phosphorus may have been lost, but the overall nutrient level remains relatively adequate. Eroded Sample "B" and Sample "C" have lower variability (SD = 0.06 mg/kg), indicating more consistent phosphorus levels within these samples.

The uneroded soil has a moderate variability (SD = 0.10), suggesting a relatively uniform phosphorus distribution in undisturbed conditions. Furthermore, Nitrogen (N) levels in soil are crucial for plant growth and overall soil fertility, as nitrogen is a key nutrient for plants. Comparing nitrogen levels in eroded and uneroded soil samples helps to understand how erosion affects soil quality and nutrient availability. Eroded Sample "A" shows a higher nitrogen level (77.63) compared to the uneroded soil (70.30). This might indicate that the area has received nitrogen from external sources, possibly from fertilizers or organic matter deposition, leading to an increase despite erosion. This could be beneficial for plant growth but might also lead to nitrogen leaching or runoff, especially with higher variability indicated by the SD of 0.5.

Eroded Sample "B" has a significantly lower nitrogen level (56.17) than the uneroded soil. This suggests substantial nitrogen loss due to erosion, which could negatively affect soil fertility and crop productivity. The low SD (0.2) indicates consistent nitrogen depletion across this sample. Eroded sample "C" has a nitrogen level (67.53) slightly below the uneroded soil level, indicating moderate nitrogen loss. The low SD (0.1) suggests a relatively uniform nitrogen distribution despite the erosion impact.

The standard deviations provide insight into the variability of nitrogen levels within each sample. Sample A and the uneroded soil both have higher SD (0.5), indicating more variability in nitrogen levels, possibly due to patchy erosion or varying input sources.

Sample "B" and Sample "C" have lower SDs (0.2 and 0.1, respectively), suggesting more consistent nitrogen levels within these samples.

3.2.3 Zinc Concentration in Eroded and Uneroded Soil

Zinc (Zn) is an essential micronutrient for plant growth, playing a crucial role in various physiological functions. The levels of zinc in soil can significantly affect soil fertility and, consequently, plant health and yield.

Eroded sample "A" has a Zinc level (10 mg/kg) is relatively low, which might be near the deficiency threshold for many crops. The high standard deviation (7.4 mg/kg) indicates considerable variability in zinc levels within this soil type. This variability could result in inconsistent crop growth, with some areas potentially experiencing zinc deficiency while others have sufficient levels.

Eroded sample "B" has a Zinc level (15.58 mg/kg) is moderately higher than in Soil A but still shows significant variability. The high standard deviation (12.24 mg/kg) suggests that zinc levels are unevenly distributed. Some areas might have adequate zinc levels, while others might not, potentially lead to uneven crop performance.

Eroded sample "C" has a Zinc level (23.51 mg/kg) the mean zinc level is high, indicating that the soil is likely to be fertile concerning zinc availability. The low standard deviation (1.36 mg/kg) suggests that zinc levels are consistent throughout the soil, which is beneficial for uniform crop growth and health.

Eroded sample "U" has a Zinc level similar to Soil C this soil has a high mean zinc level, suggesting good fertility. The standard deviation is slightly higher than in Soil C but still low enough to indicate relatively uniform zinc distribution. This consistency is also favorable for consistent crop growth.

3.2.4 Copper Concentration in Eroded and Uneroded Soil

Copper (Cu) is another essential micronutrient for plant growth, playing a crucial role in photosynthesis, enzyme activity, and overall plant metabolism. The concentration of copper in soil, especially in eroded versus uneroded soil, can significantly affect soil fertility and plant health. The mean copper level for eroded soil sample "A” is moderately low (2.26 mg/kg), with a high standard deviation (2.33 mg/kg) indicating significant variability. This suggests that the copper concentration is unevenly distributed, leading to potential areas of deficiency and excess, causing inconsistent crop growth.

This soil "B" has the highest mean copper concentration (3.82 mg/kg) among the eroded soils. The standard deviation (1.45 mg/kg) is moderate, indicating less variability than Soil A but still some inconsistency. Overall, the higher mean copper level is beneficial for plant growth, although the variability might still cause some uneven growth. The mean copper level for eroded soil sample "C" is the lowest (1.90 mg/kg) among the eroded soils, with a relatively low standard deviation (1.11 mg/kg). The lower variability suggests more uniform copper distribution, but the overall low copper concentration may lead to deficiencies in plant nutrition

The mean copper level in uneroded soil is the lowest (1.29 mg/kg) among all samples, with the standard deviation equal to the mean, indicating substantial variability. This suggests that copper levels are quite inconsistent, which can lead to patchy growth and areas of copper deficiency.

3.2.5 Iron Concentration in Eroded and Uneroded Soil

Iron (Fe) is a critical micronutrient for plants, essential for chlorophyll synthesis, enzyme function, and overall plant metabolism. The levels of iron in soil can greatly influence soil fertility and plant health.

The mean iron level in uneroded soil sample "A" is quite low (1.74 mg/kg) and the high standard deviation (1.59 mg/kg) indicates significant variability. This variability suggests inconsistent iron availability, which can lead to areas of iron deficiency, affecting plant health and growth negatively. This soil "B” has a higher mean (3.98 mg/kg) iron concentration with moderate variability. The higher iron levels are more favorable for plant growth, and the moderate standard deviation (0.60 mg/kg) suggests more consistent iron availability compared to Soil A, leading to better overall soil fertility.

Eroded sample "C" is similar to Soil B; this soil also has a relatively high mean iron level (3.85 mg/kg) with low variability. The low standard deviation (0.43 mg/kg) indicates a uniform distribution of iron, which is beneficial for consistent plant growth and soil fertility. The uneroded soil has the highest mean iron level (4.72 mg/kg) and the lowest standard deviation (0.07 mg/kg, indicating uniform iron distribution. This consistency in high iron availability is ideal for optimal plant growth and soil fertility, reducing the risk of iron deficiency and ensuring even plant development.

3.2.6 Manganese Concentration in Eroded and Uneroded Soil

The mean Manganese level in uneroded soil sample "A" (8.65 mg/kg) is moderately high, and the low standard deviation (0.18 mg/kg) indicates consistent distribution. This consistency is favorable for uniform plant growth, although the manganese level is slightly lower compared to other soils, which might necessitate occasional supplementation for optimal fertility.

3.2.7 Manganese Concentration in Eroded and Uneroded Soil

The mean Manganese level in uneroded soil sample "B” This soil has a mean (9.55 mg/kg) concentration and even lower variability than Soil A. The higher manganese level and consistent distribution make Soil B more fertile, supporting healthy and uniform plant growth.

This soil has the highest manganese level (9.99mg/kg) among the eroded soils but also the highest variability. While the higher manganese level is beneficial, the variability could lead to slight inconsistencies in plant growth, although it is still relatively low.

The uneroded soil has the highest mean manganese level (10.44 mg/kg) and low variability, indicating a uniform distribution. This high and consistent manganese availability is ideal for optimal plant growth and soil fertility, reducing the risk of manganese deficiency and ensuring even plant development.

3.2.8 Sodium Concentration in Eroded and Uneroded Soil

The mean Sodium level in uneroded soil sample "A"(6.03mg/kg) level is moderately high, with a relatively low standard deviation (0.32 mg/kg) indicating consistent distribution. While the sodium level is within a tolerable range for many plants, it is approaching levels that might begin to impact soil structure and plant health negatively, especially for sodium-sensitive crops.

This soil has a higher sodium concentration (8.22 mg/kg) than Soil A, with very low variability. The higher sodium level could lead to salinity issues, potentially affecting plant growth and soil structure negatively. Careful management and potentially remediation might be necessary to mitigate these effects.

The mean Sodium level in uneroded soil sample "C” (8.37 mg/kg) Similar to Soil B, this soil has a high sodium level with very low variability, indicating consistent distribution. The high sodium concentration poses a risk of soil salinity, which can adversely affect plant growth and soil health, requiring careful management.

The uneroded soil has a significantly lower sodium concentration compared to the eroded soils, with extremely low variability, indicating very consistent distribution. The low sodium level is beneficial for plant growth and soil structure, reducing the risk of salinity-related issues.

3.2.9 Calcium Concentration in Eroded and Uneroded Soil

Calcium (Ca) is a crucial secondary nutrient for plants, playing a vital role in cell wall structure, membrane function, and enzyme activity. It also helps in maintaining soil structure and mitigating soil acidity. The mean Calcium level in eroded soil sample” A” (2.31mg/kg) is relatively low, but the very low standard deviation (0.01 mg/kg) indicates consistent distribution. While uniform, the low calcium concentration may necessitate supplementation, particularly for crops with higher calcium requirement. This soil has a higher mean calcium concentration (3.58mg/kg) but the high standard deviation (0.88mg/kg) indicates significant variability. This variability can lead to uneven calcium availability, potentially causing inconsistent plant growth and necessitating targeted calcium amendments to address deficiencies.

The mean calcium level (3.14 mg/kg) is moderately high, with low variability, indicating consistent distribution. This is beneficial for plant growth, though the overall calcium level might still be on the lower side for some crops, requiring occasional supplementation.

The uneroded soil has the highest mean calcium level (4.87 mg/kg) and very low variability, indicating highly consistent distribution. This high and uniform calcium availability is ideal for optimal plant growth and soil fertility, reducing the risk of calcium deficiency and ensuring even plant development. The uneroded soil sample has the highest calcium concentration and low variability, making it the most fertile among the samples. The high and consistent calcium availability ensures optimal plant growth and soil health.

4.0 SUMMARY, CONCLUSION AND RECOMMENDATION

4.1 Summary

Understanding the levels of trace, macro and secondary nutrients in eroded versus uneroded soil samples highlights the need for effective soil management practices to sustain agricultural productivity and environmental health as revealed from the results obtained from this research work**.** Both eroded and uneroded soil exhibits arears of strength and weaknesses as they show varying levels of different elements required for healthy plant growth, indicating the effect of erosion on soil composition in the study area. Soil conservation practices should be implemented to reduce erosion, particularly in areas showing significant depletion for various elements required for plant growth.

4.2 Conclusion

The study reveals that variations exist in the composition of macronutrients, micronutrient and secondary nutrients required by plants.it also shows the effect of soil erosion in the study area as expressed in the decrease in nutrient composition across eroded soils.

4.3 Recommendations

i) Regular soil testing is necessary to monitor nutrient levels and assess the effectiveness of erosion control measures. ii) Employ erosion control measures to reduce soil and nutrient loss, ensuring long-term soil health and sustainability.

iii) Soil management practices such as adding copper fertilizers or organic matter could help address these deficiencies and improve soil fertility.

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