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Consideration of the Levels Exchangeable Cations and Selected Anions in Soils of Ethiope River Plain

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Abstract. The cation exchange capacity (CEC) (K⁺, Mg²⁺, Na⁺, Ca²⁺) and anion exchange capacity (AEC) [S²⁻ and P₂O₅ (oxide)] of the topsoils and subsolos of Urhuoka and Urhuovie were determined using Atomic absorption spectrophotometer (AAS) and X-ray fluorescence spectrometry respectively. In the subsolos of Urhuoka, the concentration of cations (1097 ± 1.01 mg/kg) was slightly more enriched than the topsoils (1047 ± 0.96 mg/kg). However, this trend was reversed in Urhuovie where 763.50 ± 0.34 mg/kg and 947.41 ± 0.64 mg/kg respectively was reported. The difference in concentrations between the two layers of soil for some cationic species may be explained in terms of accumulation of detritus in the topsoil. The pseudo-concentration of CEC by bases was higher in soils of Urhuoka (5.69 ± 0.08 and 5.49 ± 0.06 mol/kg) than Urhuovie (4.29 ± 0.05 and 3.24 ± 0.03 cmol/kg) for the top and subsoil respectively. There was significant difference at levels of P < 0.05 between exchangeable cations and the total fraction for the bases. However, since the soils were acidic to slightly acidic and low in exchangeable bases, there is the need to use organic fertilizers as well as liming so as to enhance the soil pH and nutrient levels if the plain is to be used for intensive agriculture.

Keywords: exchangeable bases, fertility, macronutrients, river plain, soil

List of abbreviations
Analysis of variance (ANOVA); Anion exchange capacity (AEC); Atomic absorption spectrophotometer (AAS); Cation exchange capacity (CEC); Effective CEC (ECEC); Kilocount per sec (kps); Organic matter (OM); Parts per million (ppm); Specific gravity (sp gr); Statistical Package for Social Science (SPSS)

1. INTRODUCTION

Soil is an especially important natural resource that is essential for life. Soil acts as the habitat for living organisms and it supports the growth of plant that makes life possible for humans and other land animals. It is from the plants that grow on soils that food for our daily sustenance comes from. Soil also acts as a filtration system for surface water, carbon store and maintenance of atmospheric gases (Brady, 1974; Ekwoanya and Ojanuga, 2002). Thus the soil, together with the plant and animal life it supports, the rock on which it develops, its position in the landscape and the climate it experiences, form an amazingly intricate natural system – more powerful and complex than any tool that man has created. Medicinal plants used for the cure of various diseases and sicknesses such as fever, enzyma, ringworm etc. are got from the soil.

Cation exchange capacity (CEC) is the amount of exchangeable cation per unit weight of dry soil. CEC is a measure of the ability of the soil to hold positively charged ions. It is measured in milliequivalents of cation per 100 g of soil (meq/100g) or centimoles of charge per kilogram of exchanger (cmol(+)/kg). The former unit was used in older publications. It should be remembered, however, that values presented in either meq/100 g or cmol(+)/kg are equivalent (Reeuwijk, 2002; Orji and Obasi, 2012).

Cations are positively charged ions and the exchange of one positive ion by another is called cation exchange. Thus when an ammonium fertilizer with its cation, NH₄⁺ is added to soil, many of the numerous ammonium ions replace other cations already absorbed to the exchange sites. The clay
mineral and organic matter (OM) components of soil have negatively charged sites on their surfaces as well as on the surface of plant roots, which adsorb and hold positively charged ions (cations) by electrostatic force. This electrical charge is critical to the supply of nutrients to plants because many nutrients exist as cations (e.g. potassium, magnesium, sodium and calcium). In general, soils with large quantities of negative charge are more fertile because they retain more cations, however, productive crops and pastures can also be grown on low CEC soils. The ability of a soil to hold cations in exchangeable forms is a property of its fine mineral particles and humus components (McKenzie et al., 2004).

The main ions associated with CEC in soils are the exchangeable cations - potassium (K⁺), magnesium (Mg²⁺), sodium (Na⁺) and calcium (Ca²⁺) and are generally referred to as base cations (Rayment and Higginson 1992). In some cases, summing the analyzed base cations gives an adequate measure of CEC (‘CEC by bases’). However, as soils become more acidic these cations are replaced by H⁺, Al³⁺ and Mn²⁺. When exchange acidity (H⁺, Al³⁺) is included in summing the base cations, the measurement is referred to as effective CEC (ECEC) (Gedroiz, 1929; Chapman, 1965; McKenzie et al., 2004). Cation exchange capacity (CEC) is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil’s reaction to fertilizers and other ameliorants (Hazleton and Murphy, 2007). Cation exchange capacity is also an important phenomenon for two reasons: one is that exchangeable cations such as potassium, magnesium, calcium and sodium are readily available for plant uptake and the other is that cations adsorbed to exchange sites are more resistant to leaching, or downward movement in soils with water.

The amount of exchangeable cation in the soil can be determined by using a method which yield results of each element and also by summation of values obtained by individual determination of Ca²⁺, Mg²⁺, K⁺, and Na⁺ (‘CEC by bases’). In addition to providing a source of plant available cations, exchangeable cations also affect the physical properties of a soil. Cation exchange is an important reaction in soil fertility, correcting soil acidity and basicity, altering soil physical properties and as a mechanism in purifying and altering percolating waters. Thus, soil acts as a large exchanger.

Colloids that have an appreciable anion exchange are those that also have low cation exchange. Anion exchange is analogous to cation exchange and is a measure of the ability of soil particles to absorb and exchange anions (measured in cmol(-)/kg or meq/100g soil). Anion are negatively charged ion (NO₃⁻, SO₄²⁻, Cl⁻, PO₄³⁻, S²⁻). Relatively, most soils have little or no AEC. Multi-charged positive ions, such as iron and aluminium, have hydroxyls (OH⁻) that can be exchanged with sulphate (SO₄²⁻), phosphate (H₂PO₄⁻ or HPO₄²⁻), molybdate (MO₃⁴⁻) and some other anions. Mehlich, (1953) made anion exchange determination using the phosphate ion as index, which was particularly suitable for the purpose.

In this evaluation, the major exchangeable cations (Ca²⁺, Mg²⁺, K⁺, Na⁺) (‘CEC by bases’) and anions (P₂O₅ and S⁴⁻) in soils of Ethiope River plain in the Niger Delta ecological zone of Nigeria was determined. There is now renewed interest and emphasis on commercial agriculture in the quest for diversified economy. The utilization of the Ethiope River plain (Uruhuoka and Urhuovie) in intensive agriculture will depend on the nutrient availability in the soil.

2. MATERIALS AND METHODS

2.1. The study area

The Ethiope River plain is a part of the coastal plains in the Niger Delta ecological zone of South-Western Nigeria (Figure 1). Land elevation is generally below 45 metres above mean sea level. The Ethiope River rises from Umuaja, a village near Umutu in Ndokwa East local Government Area, Delta State. The river flows westward into the Benin Creek. The georeference for the sampling zone lies between latitudes 5°40'6''N and 6º00'N and longitudes 5º39'5''E and 6º10'9''E. The areas under study fall within the rainforest zone. The climate is usually hot and humid with distinct wet and dry seasons. The wet season is usually longer than the dry season. The former lasts from March to October. No month is entirely dry without little rainfall, but lowest within the months of December, January and February. The mean annual rainfall of these areas varies slightly from 2000 mm to 2500 mm (Uruhuoka) and from 2032 mm to 2600 mm (Urhovie). The average mean annual temperature is between 24 - 29°C for Uruhuoka and 23 - 28°C for Urhuovie. Relative humidity is high all year round and varies between 50% and 75%. This climatic condition supports rich tropical rain forest vegetation that has been interfered with human activities and replaced by secondary vegetation such as grasses and shrubs, and scattered cultivation of rubber and palm trees.
2.2. Field studies

2.2.1. Collection and preservation of soil samples

Soil samples were randomly collected in triplicate from each sampling plot representing a zone in Urhuoka and Urhuovie from two pre-determined depths of 0 - 15 cm (topsoil) and 15 – 30 cm (subsoil). The samples collected from each zone comprised of 16 sampling points. After collection, objects such as dead weed, stems, leaves, sticks and stones were carefully removed and the soil samples were transferred into labeled poly containers. In the laboratory, the samples were spread on drying trays (free of dust or chemical fumes) to air dry. The dried samples were crushed in an agate mortar into fine powder and then sieved through a 2-mm sieve. All materials not passing through the sieve were rejected. The fractions that passed through were retained for subsequent treatment and analysis.

![Map of sampling location](image)

**Fig. 1:** Map of sampling location (Uruhuoka and Urhuovie) in Ethiope River plain of Delta State

2.3. Laboratory Analysis

2.3.1. Determination of soil pH

The pH values of the soil samples were determined in distilled water and 1N KCl using a soil to liquid ratio of 1:1. Twenty (20) g of air-dried soil was accurately weighed into a 50 mL sample container. Twenty (20) mL of deionized water and 1N KCl was then added to the soil samples in different sample containers. This was allowed to stand for 30 minutes and stirred occasionally with a glass rod. The pH of each of the samples was taken but the suspension was not stirred during measurement. The electrode was rinsed with deionised water and wiped dry with a clean tissue after each reading (IITA, 1984).

2.3.2. Determination of Cation Exchange Capacity (IITA, 1984)

Two (2) g of 2-mm soil sample was accurately weighed into a 20 cm³ centrifuge tube with stoppers. Five (5) cm³ of 1.0 M sodium acetate solution was added and shaken for 5 minutes. This was decanted
and the liquid discarded. The shaking and centrifuging was repeated three more times with fresh portions of acetate solution. The soil was then shaken with 5 cm$^3$ of 95% ethanol for 5 minutes, centrifuged and the liquid discarded. The ethanol washing was repeated three more times. Finally the soil was extracted with three 5 cm$^3$ portions of 1.0 M ammonium acetate solution and the extracts collected into a 50 cm$^3$ flask (IITA, 1984). It was necessary to filter the extracts after centrifuging to remove any insoluble materials. The combined extracts were diluted to mark and the exchangeable bases (Na$^+$, K$^+$, Mg$^{2+}$, Ca$^{2+}$) was determined using atomic absorption spectrophotometer (AAS, Shimazu 6701 F model).

2.3.4. Determination of metals content (IITA, 1984)

Two (2) g of the sieved air-dried soil was accurately weighed into a platinum crucible and moisten with one to two drops of water. The soil sample was digested in a mixture of nitric acid (5 mL), sulphuric acid (3 mL) and perchloric acid (3 mL). Filtration of the resulting solution was carried out in order to remove insoluble materials. The filtrate was then transferred into a 100 cm$^3$ volumetric flask and diluted to volume with doubly - distilled water. This was used for the determination of sodium, potassium, magnesium and calcium using atomic absorption spectrophotometer (AAS, Shimazu 6701 F model). The concentrations were read off from a calibration curve prepared with a set of each metal standard solution. All analyses, digestion and spectrophotometric measurements, were carried out in triplicate.

2.3.5. Determination of Anion Exchange Capacity (Reeuwijk, 2002)

Two (2) g of finely ground and sieved soil sample was accurately weighed and mixed in a crucible with the binder solution (20 mL of 5% N-butylmethacrylate dissolved in 100 mL acetone) until hardened. The X-ray sample plate was pelletized using a hydraulic pressing machine. The plates were allowed to stand for 5 minutes. The plate was then slotted into the X-ray tube to read the kilocount per sec (kps) on an X-ray fluorescence spectrometry, which was then converted to % concentration.

2.4. Statistical Analysis

The concentrations of metals in the soil samples were read off the spectrophotometer in mg/L. However, since 1% is equivalent to 10000 mg/L when specific gravity is 1.00, in solid samples and liquid of high specific gravity, a correction is made if the results are expressed as mg/kg, parts per million (ppm), or percent by weight: that is:

Metal concentration, mg/kg (ppm) by weight = \[
\frac{\text{mg/L}}{\text{10000 x sp gr}}
\]

Similarly, % by weight in solid matrixes can be obtained using the formula:

% by weight = \[
\frac{\text{mg/L}}{\text{10000 x sp gr}}
\]

Where: specific gravity (sp gr) = mass/volume (mass of soil used in the digestion / total volume of solution (APHA, 2009). All experiments were conducted in triplicate and used for the calculation of mean metal concentrations. The analysis of variance (ANOVA) test was performed using Statistical Package for Social Science (SPSS) statistical software in Version 21.0 to determine the significant difference between the two locations at significance levels of $P < 0.05$. Different types of graphs were used for the final pictorial representation of the different measurement variables.

3. RESULTS

The results in Urhuoka for pH ranged from 4.5 – 5.0 (KCl) and 5.0 – 5.6 (water) while Urhuovie varied from 5.5 - 6.0 (KCl) and 6.1 – 6.6 (water). The pH values in the soils were mainly acidic to slightly acidic considering the pH values in KCl (Table 1).

The mean results obtained from the experimental analysis for total and exchangeable bases in mg/kg are presented in Table 2, while the concentrations of extractable forms in cmol/kg are detailed in Table 3. The results in Table 2 showed that the pseudo-concentration of total and exchangeable cations fractions in soils of Urhuoka had higher amount in the subsoils than the topsoils while soils from Urhuovie soils was observed to be in the opposite direction. The levels of exchangeable bases from Urhuoka was about the same order of magnitude in the two soils as there was no significant difference at levels of $P < 0.05$ between the levels of the two layers.

Similarly, the variations between the exchangeable and total fraction for the bases were also significant considering the concentrations in mg/kg (Table 2). However, since the samples were collected from different spots or zones, there was sure to be some variation in concentrations for the various metals analyzed. The data for sum of exchangeable bases - (K$^+$, Mg$^{2+}$, Na$^+$ and Ca$^{2+}$) in cmol/kg for the two zones (Urhuoka and Urhuovie) are shown in Table 3.
Table 1: Soil pH ranges

| Rating | Description   | pH   |
|--------|---------------|------|
| 1      | Strongly acidic | <5.1 |
| 2      | Moderately acidic | 5.2–6.0 |
| 3      | Slightly acidic | 6.1–6.5 |
| 4      | Neutral       | 6.6–7.3 |
| 5      | Moderately alkaline | 7.4–8.4 |
| 6      | Strongly alkaline | >8.5 |

Table 2: Pseudo-concentration of total and exchangeable cations fractions in soils of Urhuoka and Urhuovie

| Parameter, (mg/kg) | Metal form | Soil layer (cm) | Urhuoka | Urhuovie |
|--------------------|------------|-----------------|---------|----------|
| (K⁺ + Mg²⁺ + Na⁺ + Ca²⁺) | Total | Topsoil – 0-15 cm | 6397 ± 3.6 | 5551 ± 1.2 |
|                      | Subsoil | 15-30 cm | 6460 ± 4.1 | 4771 ± 1.1 |
| (K⁺ + Mg²⁺ + Na⁺ + Ca²⁺) | Exchangeable | Topsoil – 0-15 cm | 1047 ± 0.96 | 947.41 ± 0.64 |
|                      | Subsoil | 15-30 cm | 1097 ± 1.01 | 763.5 ± 0.34 |

Results are expressed as mean ± SD

Table 3: Pseudo-concentration of CEC by bases in soils of Urhuoka and Urhuovie

| Parameter, (cmol/kg) | Soil layer (cm) | Urhuoka | Urhuovie |
|--------------------|-----------------|---------|----------|
| (K⁺ + Mg²⁺ + Na⁺ + Ca²⁺) | Topsoil | 0-15 cm | 5.69 ± 0.08 | 4.29 ± 0.05 |
|                      | Subsoil | 15-30 cm | 5.49 ± 0.06 | 3.24 ± 0.03 |

Results are expressed as mean ± SD

Since the base quantities are given in units of mg/kg, the following equations or conversions were used to obtain values in cmol/kg:

- Exchangeable Ca (cmol(+)/kg) = extractable Ca (mg/kg) / 200
- Exchangeable Mg (cmol(+)/kg) = extractable Mg (mg/kg) / 120
- Exchangeable K (cmol(+)/kg) = extractable K (mg/kg) / 390
- Exchangeable Na (cmol(+)/kg) = extractable Na (mg/kg) / 230

Fig. 2: Mean sum of bases ± SE in soils of Urhuoka and Urhuovie

Figure 2 contained details of the comparison of the sum of bases with the recommended preferred level. The concentrations of the sum of bases in both sampling locations were below the preferred level of 10 cmol/kg of CEC in soils. Table 4 showed the ratings for CEC in different soils. The values ascertained have been assigned to the categories 1 through 5, from very low to very high, according to Bodenkundliche Kartieranleitung, Soil-scientific mapping directive (1994). The results of the sum of bases (CEC) for this study can be considered low based on the ratings.

The mean concentrations in mg/kg of anion exchange capacity determined as an index of P₂O₅ and S are indicated in Table 5. The concentrations of sulphur (S²⁻) in the top and subsoils of Urhuoka was (164.5 ± 0.09; 143.0 ± 0.06) and Urhuovie was (159.0 ± 0.05; 127.0 ± 0.04) respectively. Similarly, P₂O₅ can also be viewed in the same line as sulphur for Urhuoka and Urhuovie soils and the values recorded for the anions were in excess of the recommended concentration range for a typical soil (Table 5).
Table 4: Typical cation exchange capacity (CEC) values for different soils

| CEC (cmol/kg) [Mass %] | Level | Designation - Rating | Comment |
|------------------------|-------|----------------------|---------|
| 0 - <4                 | 1     | very low             | Soil very low in organic matter. Typical of sandy soils. |
| 4 - <8                 | 2     | Low                  | Soil very low in organic matter. Typical of sandy soils. |
| 8 - <12                | 3     | Medium               | Pumice soils often in the range 13-18; lower fertility mineral soils in the range 15-25. |
| 12 - <20               | 4     | High                 | High fertility soils may be in the range 25-35. Also may have high clay content. |
| ≥20                    | 5     | very high            | Values typically found in peat soils. Consolidated peats typically in range 40-65; raw peat may be as high as 100. |

Table 5: Concentration of anion exchange capacity in soils of Urhuoka and Urhuovie

| Soil layer (cm)   | Parameter | Typical range in soils | Excessive | Urhuoka | Urhuovie |
|-------------------|-----------|------------------------|-----------|---------|----------|
| Topsoil – 0-15 cm | P_2O_5    | 10 – 150               | > 200     | 258.0 ± 0.28 | 247.5 ± 0.17 |
| Subsoil – 15-30 cm| (P)       |                        | 237.5 ± 0.19 | 213.5 ± 0.16 |
| Topsoil – 0-15 cm | S^-       | 5 – 50                 | > 100     | 164.5 ± 0.09 | 159.0 ± 0.05 |
| Subsoil – 15-30 cm|           |                        | 143.0 ± 0.06 | 127.0 ± 0.04 |

For ease of reference, the following conversion factor can be used. P_2O_5 x 0.4364 = P

4. DISCUSSION

Sometimes, the soil may look still and lifeless, but this impression cannot be distant from the truth. However, the various activities in it provide the medium for constant change and development through time. The soil is always responding to changes in environmental factors, along with the influences of anthropogenic activities or land use. Thus, some changes in the soil could be short termed and reversible, while others could be long-termed with a permanent irreversible feature on the soil development. The composition of the soil is very essential and without this resource, plant would not be able to get the basic mineral nutrients needed for their everyday growth and survival since human and other lower organisms depend on crops from it for their daily lives.

From the results of this research, the soil was found to be acidic to slightly acidic. Soil pH is probably the most commonly measured soil chemical property and is also one of the most informative. Like temperature, soil pH implies certain characteristics that might be associated with a soil. Since pH (the negative log of the hydrogen ion activity in solution) is an inverse or negative function, soil pH decreases as hydrogen ion, or acidity, increases in soil solution and vice-versa. Soil pH has a profound influence on plant growth as it affects the quantity, activity and types of microorganisms in the soils, which in turn influences the decomposition of crop residues, manures, sludges and other organics. It also affects other nutrient transformations and the solubility or plant availability of many plant essential nutrients. All essential micronutrients, except molybdenum, become more available with decreasing pH while phosphorus is most available in slightly acid to slightly alkaline soils (Akamigbo and Igwe, 1990).

Although studies have been carried out in some plains around Nigeria, very little could be said to have been done in the coastal plains of South-Western Nigeria (Aweto, 1981; Ekwoanya and Ojanuga, 2002; Effiong and Ibia, 2009; Orji and Obasi, 2012; Yakubu et al., 2012). Aweto, (1981) showed workable results from his experiments from South-Western Nigeria. In his research, he determined Ca, Mg, K and Na. The results obtained for topsoil were 0.25 ± 0.032, 0.21 ± 0.273, 0.08 ± 0.005 and 0.04 ± 0.005 respectively and subsoil were 0.14 ± 0.011, 0.06 ± 0.12, 0.04 ± 0.002 and 0.07 ± 0.009 respectively. Values are in milli-equivalent per 100 g i.e meq/100g or cmol(+)/kg of dry soil. He also found that the soils were sandy, acidic and deficient in mineral nutrient. These results are in agreement with those obtained from this study and similar studies done elsewhere in river plains of Nigeria (Effiong and Ibia, 2009; Orji and Obasi, 2012; Yakubu et al., 2012) except Akpan-Idiok, (2012) and Akpan-Idiok et al. (2013).

The difference in concentrations between the two layers of soil for some of the metals could possibly be as a result of the decay of plants and animals residues, which forms the humus (contains more plant nutrients in the topsoil). Also, the variations observed in Urhuoka and Urhuovie for some base content could be attributed to occasional tilling or ploughing of the soil, in which plant materials are taken from the topsoil to the subsoil and when this occurs the subsoil now tends to have more soil nutrient concentrations than the top soil, however these concentrations are not fully retained due to heavy rainfall that prevails all the year round in the study area (Nyle, 1974). The length of rainy season and total annual rainfall are considerably very high in these plains. The topsoil could be regarded as a nutrient pool for most plants but due to heavy and frequent rainfalls, the subsoil, which now
contains very few nutrients, is exposed and cannot give sufficient crop yield.

Since the AEC of most agricultural soils is small compared to their CEC, mineral anions such as nitrate (NO$_3^-$) and Cl$^-$ are repelled by the negative charge on soil colloids. These ions remain mobile in the soil solution and thus are susceptible to leaching. The actual leaching of phosphates and sulphur usually occurs under the influence of high rainfall. Apart from the rainfall effect, great difference is found in the natural supplies of phosphates and in most soils, the availability of the soil phosphorus is usually low except when boosted with fertilizers. Phosphorus is important for seed germination and root development. Fields with low phosphorus levels may not have well-developed root systems, leading to heavily-stressed plants during droughts. Similarly, sulphur comes naturally from regional rocks and acid rain. Most sulphur is found in organic matter and must be converted to sulphate for the crop to use it. Sulphur deficiency could be subjected to severe leaching and erosion following reclamation from bush conditions (Russell, 1937; Jenny and Overstreet, 1939).

Most soil nutrients (Ca$^{2+}$, Mg$^{2+}$, Na$^+$, K$^+$, S$^2-$ etc.) used by plant in a given season comes from exchangeable and soluble forms. In the absorption of these elements, the semi-permeable membranes of the cells of the epidermic of the root are found to be highly selective that is, an element that is required by the plant is absorbed even if its quantity in the soil is relatively small. On the other hand, even when elements are found in relatively large quantities e.g. (K$^+$, Mg$^{2+}$, Ca$^{2+}$) in the soil, only very small amounts may be absorbed. It is only dissolved substances that can enter the root of plants. Similarly, when metals are present in their oxide forms in the soil, the plant cannot absorb them in these forms. They have to be converted to the exchangeable or soluble forms before they can be used by the plant (Maynard and Lorenz, 1979; Effiong and Ibia, 2009; Yakubu et al., 2012).

Also, the patches of vegetation that occurs in the heart of these zones in the Ethiope River plains are virtually treeless especially those in the lower parts of the river flood plains. The absence of trees appears to be mainly due to flooding coupled with burning when the flood waters recede during the dry season. Considering the concentrations reported for the study area, leaching, burning (exposure of topsoil to erosion) and chemical corrosion promoted by heavy rainfall, climate condition, soil types, tilling of the soil, high soil acidity, deforestation, and poor management culture are bound to affect the concentration of these elements and further reduce their values in the areas. Thus, the low level of exchangeable bases in the soil is an indication of heavy leaching of soil basic nutrients (Scott, 2006; Orji and Obasi, 2012).

The soils from this study area were sandy loam, slightly acidic and low in base mineral nutrients, however, this could still make farming of some crops suitable. At present the soils are not intensively used for farming purpose, but as population pressure on land increases, farmers would gradually encroach into these patches and are likely to make a more intensive use of the soils in the future. Since, the soils in both regions contained low amount of the basic mineral nutrient; an attempt to use the soil for sustained cropping would involve the use of fertilizers. It is envisaged that any problem of increased food production in these zones would invariably be tied with soil improvement and conservation.

Furthermore, liming to increase soil nutrient availability and boost the soil pH may be necessary, in view of the fact that the pH in Urhuoka soils was acidic while Urhuovie was slightly acidic. In the same vein, the net negative electrical charge on the soil particles constitutes part of the soil’s cation exchange capacity that is, the ability of the soil to hold nutrient cations and exchangeable hydrogen. Nutrient cations (Ca$^{2+}$, Mg$^{2+}$, Na$^+$, K$^+$) are attracted to negative exchange sites, which cannot be easily washed away physically by heavy rains or drainage except the pH of the environment drops below 3 pH units.

5. CONCLUSION

The study revealed that the soils from the Ethiope River plain were acidic and relatively low in exchangeable bases (CEC by bases), which would make it difficult to support the growth of certain crops. The results from this study revealed that there is the need to employ some conservation practice to ensure a sustainable land use practice especially for agricultural purposes if the areas are to be explored. Practices like crop rotation, cover cropping and mixed farming system should be more frequently employed to prevent leaching of basic soil nutrients. However, if the river plain in the study area is to be used for intense farming and agricultural activities, organic fertilizers as well as liming should be employed to enhance the soil pH and essential nutrient levels. Inappropriate agricultural management and practices such as bush burning, deforestation and overgrazing should be discouraged since they are likely contributors to nutrient depletion in the soils occasioned by heavy rainfalls and erosion suffered in the river plain of this region. Thus, it can be concluded that the river plains in Ethiope River could only support certain crops that the soil environmental conditions could tolerate.
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