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RESEARCH ARTICLE

LABORATORY ANALYSIS OF SOIL PHYSICO-CHEMICAL PROPERTIES BASED ON AGRICULTURAL FERTILIZER INPUT REQUIREMENT APPLICATION: A CASE OF HARAMAYA UNIVERSITY, ETHIOPIA

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ABSTRACT

This study aimed at assessing the soil with detail information about soil properties that are basic for agricultural input requirements such as fertilizer application. It was guided by the specific objectives which include identifying the different steps taken to undertake soil physical, chemical properties and providing basic data on the physical and chemical properties of the selected soil sampling site at Haramaya University, Ethiopia. The laboratory analysis aimed at finding out the physical and chemical soil properties on the deliberate selected area indicated sand-loamy, clayey and sand. The profiles shows some variations in the patterns of the horizons within a profile. Among the soil chemical characteristics, it was found that the soil pH in soil-water suspension varied from 7.63-7.65. Electro-conductivity was very low varying from 0.08 to 1.00 ds/m with an average value of 0.54 ds/m. The maximum exchangeable sodium percentage (ESP) value calculated is 6.36 % where the minimum is 0.36 % and averaged value of 3.36 %. Cation Exchange Capacity ranged from 13.20 to 40.38cmol (+)/kg of soil, with mean value of 27.94 cmol (+)/kg. Exchangeable calcium ranged 4.99 cmol (+)/kg to 18.34 cmol (+)/kg with a mean of 12.02 cmol (+)/kg which is rated as high. The potassium value of (0.05, 0.82 meq/100gm), 0.06 meq/100gm and (0.13, 0.46 meq/100gm) of soil respectively. The value of the measured exchangeable sodium ranged from 0.12 to 1.22 meq/100g of soil, with a mean value of 0.44 meq/100g of soil indicating medium sodium content of the soil. Total nitrogen ranging from 0.11 to 0.37 percent which decreases from top to sub soil. In conclusion soil and agronomic management are correlated with the well being of soil. Therefore, it is recommended that integrated nutrient management activities should be adopted in the study area for optimum and sustainable production of major crops.

KEYWORDS

Physical and Chemical Soil, Clayey, Agronomic

1. INTRODUCTION

Climate Smart Agriculture (CSA) has been developed to address the challenges in the agriculture sector caused by climate-induced disasters and stresses (Benson, 2022; Bhusal et al., 2020; Gupta et al., 2021; Khatri-Chhetri et al., 2017; Sardar et al., 2021; Turyasingura and Chavula, 2022). CSA is defined as a strategic approach that aims to sustainably improve agricultural productivity and enhance food security, increase farmers' resilience and adaptation to climate change, and reduce and/or remove greenhouse gases (GHG) emissions where possible (Anstalt, 2013; Huyer and Nyasimi 2017; Lipinski et al., 2013; FAO, 2016). CSA helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate (Alemu and Mengistu, 2019; Joshi et al., 2019; Lipper et al., 2014).

The main causes of declining soil fertility in many parts of developing nations include poor organic matter recycling, soil erosion, and uneven

fertilization (Ayalneh, 2003; FAO, 2016; UNICEF, 2020). Bhandari (2014) notes that to improve their output, farmers carelessly employ artificial fertilizers. In violation of the climate smart agriculture principle, excessive and irrational use of chemical fertilizers degrades soil quality, which lowers crop yields and increases greenhouse gas emissions (UNICEF, 2020). The novelty from this study is that the knowledge of soil properties is necessary to transform agriculture in the face of climate change by boosting output and productivity as well as ensuring sustaining economic growth while reducing the effects of climate change (Fahad et al., 2019).

The study aimed at assessing the soil laboratory test was to come up with detailed information about soil properties which are basic for agricultural input requirements such as fertilizer applications practically. This study was guided by the specific objectives which included; identifying the different steps taken to undertake soil physical and chemical properties as in line with and providing basic data on physical and chemical properties of the selected soil at Haramaya University, Ethiopia (Mangale et al., 2016).

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This report explains how soil surveys are conducted to determine the physical and chemical characteristics of the soil; the technique used at each stage; and the results of the soil physical and chemical analysis of the corresponding identified soil sample.

2. LITERATURE REVIEW

The steps for testing the soil were broken down into the following stages: Gathering and processing soil samples Extraction and analysis of soil's physio-chemical composition and nutrient content (Subba and Somasundaram, 2020; Tagore et al., 2015).

2.1 Collection of Soil Samples

Since soil is a fairly diverse mass and soil samples themselves are typically the biggest source of error, the soil sample taken should be homogeneous and indicative of the area being examined (Zonneveld, 1989). Some researchers notes that it is necessary to cultivated, and management levels of soil (Aleminew and Alemayehu, 2020). While sampling, it is necessary to stay away from recently fertilized plots (Poeplau et al., 2018). Samples can be taken between the rows of crops as they are planted (Mascher et al., 2019). A group researchers said that zig-zagging motions should be used to collect the sample (Beck et al., 2020). A uniform field's 8–20 subsamples can be combined to create a typical composite soil sample (Dinkins et al., 2008). "When the top few centimeters of soil are dry and left out of the standard sample, a common error in soil sampling takes place (Turyasingura et al., 2022). Soil test value is based on how accurately the sample represents a field (Rogovska et al., 2019)."

2.2 How to take Representative Soil Sample

According to Cavico et al. (2012); Ravansari et al. (2020); Subba Rao and Somasundaram (2020); Tagore et al. (2015), soil samples undergo different steps in the laboratory as discussed below:

1. Divide the field into separate units depending on variation in slope, color, texture, crop growth and management.
2. Remove the debris, rocks, gravels from the surface before collecting soil sample.
3. Make a V shape cut into the soil to a depth of sampling (0-15 cm) and obtain 2 to 3 cm thick vertical slices along the depth.
4. Collect 10-15 samples randomly in zig-zag manner from each field.
5. Mix samples by quartering method and approximate 500 g of sample is retained.
6. The sample must be kept in a clear cloth or polythene bag.
7. Label it with suitable description and identification marks.
8. Send the soil samples to soil testing laboratory along with the information sheet.

2.3 Precautions to be taken during Collection of Soil Sampling

1. Remove all debris from surface before collection of soil sample.
2. Avoid taking sample from upland and low land areas in the same field.
3. Take separate sample from the areas of different appearances.
4. In row crop take sample in between rows.
5. Keep the sample in a clean bag.
6. A sample should not be taken from large area (more than 1-2 ha).
7. Sample for micronutrient analysis must be collected by steel or rust free khurpi/auger and kept in clean polythene bag.

2.4 Preparation of Soil Sample for Testing

(Bates, 1993; Jaman et al., 2021; Tan, 1995).

1. Spread sample for drying on clean cloth, plastic or brown paper sheet.
2. Remove the stone pieces, roots, leaves & other undecomposed organic residues from the samples.
3. Large lumps of moist soils should be broken.
4. After air drying the samples should be crushed gently and sieved

through a 2 mm sieve.

5. About 250 g of sieved sample should be kept in properly labeled sample bag for testing.
6. An ideal or appropriate time for soil sampling is just after harvest of the rabi crops.

2.5 Interpretation of The Results

Results of foliar diagnosis must be confirmed by plant analysis and concentration of nutrient in the soil. It will give general relationship between growth and quantity of the nutrient absorbed (Turyasingura et al., 2022). Sometimes the percentage of an element in the plant is to be judged vis-à-vis the percentage of other elements i.e. ratios of the elements are used. The interpretations of the field and laboratory data, and characterization of the soil were made using World reference base for soil resources.

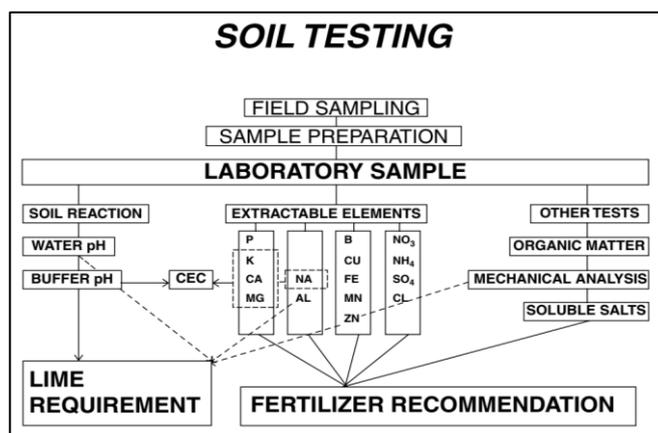


Figure 1: Sequence for conducting soil test, taken from Dr. Johan, (1930) on organic matter

2.6 Physical and Chemical Properties of Soil

Physical properties - Soil texture - Soil structure - Available water holding capacity - Bulk density - Permanent wilting point - Field capacity - Presence of organic horizon - Hydraulic conductivity - Infiltration Rate
Chemical characteristics such as "soil reaction (PH) - Organic carbon (OC) - Total nitrogen - Salinity EC and soluble salts - Exchangeable actions (Na, k, ca, mg) - Action exchange capacity (CEC) - Free calcium carbonate CaCo3) - Base sat % - ESP - Available P - Available k" (Bogale et al., 2020).

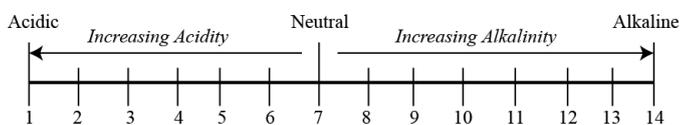
2.7 Physical and Chemical Characteristics of The Soil: Their Significance and how they are Determined

2.7.1 Soil pH (Potentiometric Method)

According to Nair et al. (2021), the pH which stands for "potential of hydrogen" refers to the hydrogen ion (H^+) concentration of a solution or soil. With reference to soils, it is alternatively known as soil reaction. It is the measure of the acidity or basicity of a solution, or of soil, and is expressed or defined as the negative logarithm of hydrogen ion concentration. It is written as; $pH = -\log(H^+)$. When the hydrogen ions concentration is high, the soil is said to be acidic, and when the hydrogen ions concentration is low, the soil is alkaline. We consider that a soil is acid when there is an abundance of acidic cations like hydrogen (H^+) and aluminum (Al^{3+}) present compared to the alkaline cations like calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K), and sodium (Na^+).

2.7.2 The pH Scale

Soil pH is measured on a pH scale. The scale runs from 1 to 14 corresponding to hydrogen ion concentration of 10^{-1} to 10^{-14} M, with pH 7 being the neutral point.



The pH values above 7 are alkaline and those less than 7 are acidic. This means that the lower the pH, the more acidic the solution is, i.e. solutions with a low pH values are strongly acidic while those with high pH values are highly alkaline.

2.7.3 Importance of Soil pH

Soil response has a strong stimulus on the availability of various nutrients to the plant e.g. at a low pH (acidic reaction), phosphorous is "fixed" in the soil and, like molybdenum; it is rendered unavailable for plant use. On the other hand, at high pH (alkaline reaction), some plant nutrients become unavailable. Boron, zinc, manganese, potassium and iron are less available above pH 8.5, and nitrogen is usually available only between pH 6 and 8.

A group of researchers mentioned that the soil reaction has a definite influence / effect on quantitative and qualitative composition of soil microorganisms (Abba et al., 2020). Most of the soil bacteria prefer a neutral or slightly alkaline reaction between pH 4.5 and 8.0 and fungi grow in acidic reaction between pH 4.5 and 6.5 while Actinomycetes prefer slightly alkaline soil reactions.

Soil response also effects the type of the bacteria existing in soil e.g. nitrifying bacteria (*Nitrosomonas* & *Nitrobacter*) are absent totally or inactive in acid soils, while Sulphur oxidizing bacteria like *Thiobacillus thiooxidans* are active in acidic soils.

Furthermore, each crop has its own pH range in which it grows well. Cotton prefers a pH of 5 to 6 while rice does well between pH 5 and pH 6. Tea prefers acidic soils i.e. pH 4 to pH 5, while oats can tolerate alkaline soils.

It also affects the prevalence of certain plant pathogens. At low soil pH, fungal plant diseases are more prevalent than bacterial diseases. Hence, a disease such as potato scab which is caused by a bacterium, *Streptomyces scabies*, is prevalent in soils with high pH, while fungal diseases like club root disease (*Plasmodiophora brassicae*) prevail in soils with low pH.

2.7.4 Experiment to Determine the pH Value of Soil Sample

2.7.4.1 Apparatus

- The pH meter with glass-calomel combination electrode
- Automatic stirrer with time
- Beakers
- Analytical balance with 0.1g precision

2.7.4.2 Reagents

- Distilled water

2.7.4.3 Procedure

- Weigh 10 g of dried soil sample and add into beakers.
- Then 10 ml of distilled water from the measuring cylinder were added for 1:2.5 soil/water suspensions.
- The beaker contents were transferred to an automatic stirrer and stirred for 1 minute.
- Wait for 25-30 minutes for suspension and measure pH by using pH meter.
- The pH was measured after 30 minutes on the upper part of the suspension at an accuracy of 0.1 units.
- Then analyze the result.

2.7.4.4 Soil Electrical Conductivity

According to soil electrical conductivity (EC) measures the ability of soil water to carry electrical current (Rhoades et al., 1989). Electrical conductivity is an electrolytic process that takes place principally through water-filled pores (Corwin and Lesch, 2005). A group researchers found out that cations (Ca^{2+} , Mg^{2+} , K^+ , Na^+ , and NH_4^+) and anions (SO_4^{2-} , Cl^- , NO_3^- , and HCO_3^-) from salts dissolved in soil water carry electrical charges and conduct the electrical current (Karroum et al., 2019; Kretchy, 2014). Consequently, the concentration of ions determines the EC of soils. In agriculture, EC has been used principally as a measure of soil salinity; however, in non-saline soils, EC can be an estimate of other soil properties, such as soil moisture and soil depth (Turyasingura et al., 2022). EC is expressed in Deci Siemens per meter (dS/m).

2.7.5 Experiment to Determine the Electrical Conductivity of Soil Sample

2.7.5.1 Apparatus

- The dip cells
- Automatic stirrer with time.

- Beaker
- Thermometer

2.7.5.2 Reagents

- Distilled water

2.7.5.3 Procedure

- 10 g of air-dried soil sample were weighed and put into beakers.
- Then 10 ml of distilled water from the measuring cylinder were added for 1:2.5 soil/water suspensions.
- The beaker contents were transferred to an automatic stirrer and stirred for 30 minutes.
- Wait for 25-30 minutes for suspension and measure pH by using pH meter.
- Measure the electrical conductivity.

2.7.5.4 Results

- Using the dip cell inserted in the extract, the temperature (T) recorded was 19.5°C and the Electrical conductivity of the soil (EC_t) got at this temperature was 78.1 μS equivalent to 78.1 $\times 10^{-3} \text{dS m}^{-1}$
- Therefore, the Electrical conductivity of the soil (EC_{rt}) at room temperature (25°C), is got from the formula; -

$$EC_{rt} = \frac{EC_t}{t_f}$$

Using this equation analyze the results.

2.7.6 Soil Organic Carbon

Soil organic carbon (SOC) is the main source of energy for soil microbes, according to (Lehmann and Kleber, 2015). The SOM percentage in which SOC is located affects how quickly and easily it becomes accessible (Baldock and Nelson, 2000). Accordingly, SOC can be divided into portions based on the dimensions and rates of breakdown of the SOM in which it is housed (Zimmermann et al., 2012). The SOM active pool includes the first three fractions. The carbon sources in this pool are rather simple to degrade. SOC varies along the slope gradient as a result of carbon loss due to soil erosion. SOC is typically substantially higher on level topography than on other slope classifications.

2.7.6.1 Apparatus

- Erlenmeyer flask
- Pipette
- Burette
- Analytical balance
- Magnetic stirrer
- Incandescent lamp

2.7.6.2 Reagents

- Sulphuric acid
- Potassium dichloromate
- Orthophosphoric acid

2.7.6.3 Procedure

- 1g of air-dried soil was transferred to Erlenmeyer flask.
- 10 mls of 1N potassium dichloromate ($\text{K}_2\text{Cr}_2\text{O}_7$) solution were transferred using the pipette into both the sample and the blank.
- 20ml of concentrated Sulphuric acid were added with the measuring cylinder, in the fume cupboard and the flask was swirled. The flask and its contents were allowed to wait for 30 minutes.
- 200ml of distilled water were added, and time given to allow cooling.
- 10ml of concentrated orthophosphoric acid were added. Also 5 drops of barium diphenylamine sulphonate indicator was added.
- Both the sample and the blank were filtered with 0.5N ferrous sulphate solution drop by drop until the color changed to deep green.

2.7.6.4 Results/ outcomes

- "N (normality of ferrous sulphate solution) = 0.5
- V1 (ml ferrous sulphate solution used for blank) = 17.9
- V2 (ml ferrous sulphate solution used for sample) = 12.2
- W (weight of the air-dry sample in gram) = 1
- Mcf (Moisture correction factor) = 1"

The percentage of soil organic carbon was calculated from the formula: -

$$\%C = N \times \left(\frac{V1 - V2}{w} \right) \times 0.39 \times mcf$$

$$\%C = 0.5 \times \left(\frac{17.9 - 12.2}{1} \right) \times 0.39 \times 1$$

Therefore, said that the percentage of soil organic carbon in soil sample was = 1.11% (Mangale et al., 2016). Practices such as no-till may increase SOC. Other practices that increase SOC include continuous application of manure and compost, and use of cover crops. Burning, harvesting, or otherwise removing residues decreases SOC.

SOM contains approximately 58% C; therefore, a factor of 1.724 can be used to convert OC to SOM. There is more inorganic C than TOC in calcareous soils (Zimmermann et al., 2012). TOC is expressed as percent C per 100 g of soil. From this, the soil organic matter content can be calculated from the formula; -

$$\%OM = \%C \times 1.724.$$

Also, the estimated total nitrogen percentage (%TN) can be got from the formula; -

$$\%TN = \frac{\%OM}{20}$$

2.7.7 Exchangeable Bases

The sum of the bases (calcium, magnesium, potassium, and sodium) in exchangeable form, expressed as milligram equivalents per 100 g of soil, is referred to as "exchangeable bases" or "total exchangeable bases (Ukabiala, 2022)." Compared to soils in humid locations, arid soils have more exchangeable bases and less exchangeable hydrogen. Important characteristics of soils and sediments include the quantity of exchangeable bases and the cation exchange capacity (CEC). They discuss a soil's capacity to support plant development, hold onto nutrients, buffer acid deposits, or trap harmful heavy metals. The negative charges that soil particles, particularly clay minerals, sesquioxides, and organic matter, carry lead to cation exchange. The uptake of cations from solution cancels out these negative charges. The CEC can be estimated by summation of exchangeable bases (Ca, Mg, Na, K) and exchangeable Al. The neutral (pH 7.00) 1.00 M ammonium acetate (NH₄OAc) extraction is the most widely applied method to estimate the soluble and rapidly exchangeable pools of alkali and alkaline elements in soils.

2.7.8 Principle

The soil sample is extracted with a 1 M NH₄OAc solution at pH =7.00. The soil-solution slurry is shaken for 2 hr, and the solution is separated from the solid by centrifugation. The addition of NH₄⁺ in excess to the soil displaces the rapid exchangeable alkali and alkaline cations from the exchange sites of the soil particles. The concentration of K is subsequently analyzed by ICP-OES.

2.7.9 Determination of Exchangeable Bases: Potassium

2.7.9.1 Apparatus

- Filter paper
- Beaker
- Pipettes
- Analytic balance
- Flame photometer
- Glass funnel
- Hot plate
- Atomic absorption spectrometer

2.7.9.2 Reagents

- 10ml orthophosphoric acid
- 200ml distilled water
- 100ml ammonium acetate (25ml drop four times)

2.7.9.3 Procedures

- 5g of soil was weighed and 200ml of distilled water were added to beaker with 100ml of ammonium acetate 1M of pH 7.0 solution
- The solutions were stirred with stirring rod and allowed to stand overnight while taking the precaution to cover the beakers with watch glass
- Next day, the solution was transferred onto filter funnel placed on volumetric flask and the remained soil was washed with ammonium acetate pH 7.0 into funnel while making sure that each filtration was completed after the next was finished.
- The flask was removed and brought up to volume with distilled water

2.7.9.4 Soil Texture

Soil texture is the fineness or coarseness of a soil. It describes the relative proportions of sand (large particle), silt (medium sized particle), and clay (small particle) in a soil. It is often the first and most important property to be determined when describing a soil. The soil separates are defined in terms of diameter in millimeters of the particles. Soil particles more than 2 mm in diameter are excluded from soil textural determinations. The following simple experiment demonstrates the different sizes of particles present in the soil.

2.7.10 Experiment to Determine the Texture or Textural Class of Soil Sample

2.7.10.1 Apparatus

Volumetric flask, weighting balance, graduated cylinder, hydrometer, stopwatch, oscillatory shaker, Sieve

2.7.10.2 Reagent

- Dispersing agent (40g of sodium hexametaphosphate mixed with 10g of sodium carbonate, in distilled water)
- Distilled water

2.7.10.3 Procedure

- 50g of soil were adding into a beaker.
- 100ml of dispersing agent were added.
- The contents of the beaker were shaken on oscillatory shaker for 1hr.
- The soil and the solution (beaker contents) were transferred into a cup of a mechanical stirrer by washing the bottle very well and the volume brought to 1000ml in the cup and flinger foe 40sec. Then the contents were shaken for 5 minutes.

3. MATERIALS AND METHODS

3.1 Study Area

The experiment was carried out in soil laboratory at Haramaya University which is located in East Hararghe zone of Oromia National Regional State, about 510 km East of Addis Ababa (Wondimu and Bayu, 2022). Wondimu and Bayu noted that the altitude of Haramaya University ranges from 1400 to 2340 meters above sea level, located at 42° 2' 7" E, longitude, 9°25' 15" N latitude which is located in the semi-arid tropical belt of eastern Ethiopia (Wondimu and Bayu, 2022; Hailu et al., 2019). Elevations of the site above mean sea level is gradually measured by means of altimeters, calibrated with reference to a point of known elevation, and are expressed in meters. The site is suited to an elevation of 2020 meter above mean sea level as shown in (Figure 2) below.

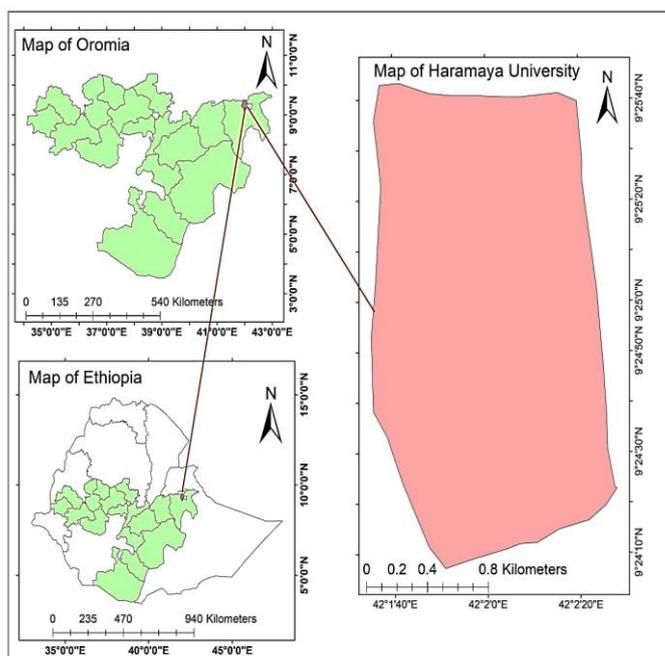


Figure 2: Study area map

3.2 Soil Survey Methodology

Even though we used the normal soil survey methodology to achieve the goal, we were only able to survey the physical and chemical soil properties of the soil parameter because of a particular problem. Three survey phases, including pre-field work, field work, and post-field work activities, were used to complete the task. The following sections contain a list of the information gathered, the tasks completed throughout each stage, and the soil parameters examined (Rurangwa et al., 2021).

3.3 Pre-Field Work

In this stage, we had to take lecture note at the laboratory about how to take soil sample by using N method or Zigzag method of sample collection by auger systems (Lejissa et al., 2022). The main work is sample collection followed by extraction or digestion and nutrient determination for measuring soil physical and chemical properties and finally interpreting the result or finding for any other recommendation (Tufa et al., 2019). The pre-field work stage includes formation of groups in which our group are group three and our potatoes' farm were assigned for us. On the other hands field survey check list and field data collection formats for soil profile description, soil auger description (Al-Shammery et al., 2018; Atanassova et al., 2018). Soil survey staffs were consulted and material for soil survey were made available.

3.4 Field Survey

The density of auger holes is discussed in this section. The auger sites were physically located on the land in the field already assigned to us which is potatoes farm found in Rare and according to selection systems for the point, 5 point were selected using zigzag method. The site conditions of every auger pit were carefully filled on the first pages of the description sheets and the auger depth of 30cm were taken for all pit (Jiménez et al., 2020).

3.5 Soil Auger

In the field we collect five sample of auger and carefully collected in the collecting plastic. In all observation sites, information like UTM coordinate and elevation (using GPS/Google Earth), were recorded which was displayed in the following photo using Google earth (Ajibade et al., 2021). Data was recorded on a standardized proforma to ensure completeness and uniformity of data collection. On-site, every Auger pit were collected, packed in to plastic bag, label it and put in air dry room without exposing to the sun. After one week, we sieve it by 2mm and 0.5mm and the later for total nitrogen and organic carbon to facilitate the reaction.

3.6 Physical Site Tests

One site tests of infiltration rates and hydraulic conductivity were not made because only texture and chemical properties of the soil were focused at the moments.

3.7 Post Field Work Activities

Prior and during this stage systematic field laboratory entry, analysis and interpretation of the result and report writing were made.

3.7.1 Laboratory analysis

The typical physical and chemical properties of soil samples taken from representative profile pits' natural horizons were examined. "The soil sample analysis was conducted out at Haramaya University soil laboratory and all analyses, except for bulk density determination, were made on air dried and crushed to pass through 2 mm sieve size (Munishi et al., 2021)." The following are the significant physical and chemical properties that were determined in laboratories using accepted techniques. The import physical and chemical parameters determined in the laboratory, based on standard methods as follows. Particle size distribution was determined by hydrometer methods following pretreatment with hydrogen peroxide (H_2O_2) to remove organic matter and dispersion aided by Sodium hexameta phosphate.

- Organic carbon (OC) was determined by a wet combustion procedure of Walkley and Black methods.
- Total nitrogen (N) was determined by the Kjeldah methods.
- Soil pH was measured in water and 1M KCL at soil /solution ratio of 1:2.5.
- Cation exchange capacity (CEC) was determined by saturation with (pH 7.0 ammonium acetate extraction, filtration) and subsequent replacement of NH_4^+ by NaCL extraction.
- Exchangeable Ca and Mg measured by following ammonium acetate leachate using Atomic Absorption spectrophotometer (AAS). Exchangeable Na and K have been measured by flame photometer. Moisture volume at field capacity (1/3 atm) and at permanent wilting point (15 atm) by pressure plate extraction.
- Available phosphorus content of the soil was determined by 0.5M $NaHCO_3$ methods of Olsen.
- Available potassium, K (Morgan's solution and flame photometer).
- Free $CaCO_3$ content of the soils was determined by acid neutralization methods.
- Electrical conductivity (EC) was determined at a soil/water ratio of 1:2.5.

From the above data other soil attributes have been derived, namely base saturation (BS), Organic Matter (OM) content, Exchangeable Sodium Percentage (ESP).

3.7.2 Calculated Parameters

The following values of parameters are calculated from the available data as follows:

- Soil Organic Matter: assuming that organic matter forms 58% of organic carbon, SOM values are obtained by multiplying values of soil organic carbon by 1.724. The value is expressed in percentages.
- Cations ratio: this is the measurement of saturations of the soils with specific cations
- Exchangeable sodium percentage, ESP evaluated from Cations exchange capacity and exchangeable sodium.
- Available water holding capacity (AWC): this is a measure of easily available soil water to be absorbed by plant roots. Obtained by the deference between field capacity and permanent wilting point and it is expressed by percentage.
- Carbon Nitrogen ratio (C: N): this measures the degree of mineralization of total nitrogen in relation to soil organic carbon level and it is obtained by dividing the value of percent organic carbon by the value of percent total nitrogen.

3.7.3 Data Compilation and Analysis

All the physical data collected in the field and the results from laboratory analysis were compiled and entered in the computer database using Microsoft words and excels.

3.7.4 Materials Used

Different soil survey materials used during field and post survey activities.

- Auger
- Munson colour chart
- Photo camera

4. RESULTS AND DISCUSSION

4.1 Soil Physical Characteristics

Characteristics of the soil utilized frequently determine whether agricultural and engineering initiatives are successful or unsuccessful. Numerous plant species' occurrence and growth, as well as the passage of water and other liquids over and through the soil, are all tightly correlated with the physical characteristics of the soil. The nature of soil solids and their influence on soil water and air, which are present in the pore spaces between the solid particles, are directly described by the physical properties. Texture, depth, structure, drainage, densities, porosity, and water content are important terms and ideas connected to soil physical attributes. The soil physical characteristics of Potatoes farm of group 3 are discussed below.

4.1.1 Texture

This was important in that, it helps determine the capacity of the soil to retain moisture and air, both of which are necessary for plant growth. Soils of the project area are dominantly loam, clay and clay loam textured throughout with some area of silty loam or silt clay texture in top soil and clay texture within sub surface of the soil depth. Laboratory analysis of soil texture shows that our soil results are Sandy loam.

4.1.2 Soil Color

The morphological description of the profiles showed some variations in the patterns of soil color both among the horizons within a profile and among the soil profiles.

4.2 Soils Chemical Characteristics

4.2.1 Soil Reaction (pH)

Soil pH is important, as it is an indicator of acidity, neutrality or alkalinity in the soil. pH helps to determine the availability of nutrients to plants and toxicity of macro and micronutrients in the soil that ultimately control plant growth. The overall pH value of the project area in soil-water suspension varies from 7.63-7.65. This soil pH is normally rated as slightly basic soil which is normal at the point when we observe its effect on nutrient availability.

4.2.2 Soil Salinity Saturated Extracts (ECSE)

A soil salinity saturation extract was prepared, allowed to equilibrate and then the saline soil water removed by suction and analyzed for EC. The range of ECe measured for the soil of the study area was very low varying from 0.08 to 1.00 ds/m with an average value of 0.54 ds/m. Generally, soil with EC value of less than 4ds/m is considered salt free soil and hence soil of the project area is not affected by salinity and no effect on the growth of plant growth as the value observed is below the permissible limit.

4.2.3 Exchangeable Sodium Percentage (ESP)

Exchangeable Sodium Percentage (ESP) indicates sodicity in the soil. Soils with ESP<15 is generally non-sodic requiring no amendments, whereas soil with ESP> 15 are sodic and requires amelioration method. The result of laboratory analysis of calculated value of ESP shows it is below the allowable limit and there is no sodicity problem in the study area. The maximum ESP value calculated is 6.36 % where the minimum is 0.36 % and averaged value of 3.36 % of the study area.

4.2.4 Cation Exchange Capacity (CEC) and Base Saturation (BS)

Cation Exchange Capacity (CEC) and the derived Base Saturation Percentage (BSP) give an overall assessment of the potential fertility of a soil and its possible response to fertilizers application. It is also important in soil classification. It should be noted that CEC values critically depend on pH. The overall values of CEC lie in the range of 13.20 to 40.38cmol (+)/kg of soil, with mean value of 27.94 cmol (+)/kg of soil. CEC values between this ranges are rated as high, which in turn mean good agricultural soil in terms plant nutrition and a little amendment was

required.

Percentage base saturation is the ratio of the sum of basic cations (Ca, Mg, Na and K) and total CEC multiplied by 100. It is frequently used as an indicator of soil fertility status and soil classification. However, the base saturation percentage does not distinguish between different bases and an imbalance in their relative proportions can cause severe plant nutrition problems. The calculated BSP of the project area was found between 47% and 77 % indicating low to high fertility rate of the soil. In other words, such higher levels of BSP mean that the exchangeable complex is saturated with exchangeable cations.

4.2.5 Exchangeable Calcium (Ca⁺⁺)

According to Sori et al. (2021), an exchangeable calcium value of greater than 6 cmol (+)/kg soil is considered to be adequate for the nutrition of most crops. The exchangeable calcium of the study area was ranges from 4.99 cmol (+)/kg to 18.34 cmol (+)/kg with a mean of 12.02cmol (+)/kg which is rated as high. The result shows that the level of Ca is higher in top all major soil and decreases downward in the soil profile.

4.2.6 Exchangeable Potassium (K⁺)

Potassium is an important plant nutrient and a great deal of study has been made of the amounts believed necessary for adequate plant growth. Values less than 0.1cmol (+)/kg soil are considered deficient, from 0.1 to 0.3 cmol (+)/kg intermediate and greater than 0.3 cmol meq/100gm adequate. Soils of the study area have exchangeable K value ranging from 0.03 to 2.22 meq/100gm soil. The lowest and the highest value is observed in Cambisols which is 0.04 meq/100gm very low k value and 2.22 meq/100gm very high k value whereas K value in the top soil of Luvisols is very low to high, Fluvisols is very low and vertisols is low to medium. The K value of these soil type is (0.05, 0.82 meq/100gm), 0.06 meq/100gm and (0.13, 0.46 meq/100gm) of soil respectively.

4.2.7 Exchangeable Sodium (Na⁺)

Although sodium (Na) may, in particular circumstances be utilized by some plants as a partial substitute for K, it is not an essential plant nutrient. Its absence or presence in only very small quantities is therefore not usually detrimental to plants but if it is high in proportion to other cations it will have an adverse effect not only on many crops but also on physical condition of the soil. The value of the measured exchangeable Na falls in the range of 0.12 to 1.22 meq/100g of soil, with mean value of 0.44 meq/100g of soil indicating medium sodium content of the soil.

4.2.8 Potassium to Magnesium Ratio (K: Mg)

If the ratio of potassium to magnesium is more than 2:1, magnesium uptake may be inhibited. The ratio of K and Mg on top soil as recorded for the project area range from 0.01 to 0.39 with an average value 0.11 which indicate an average value is at recommended level.

4.2.9 Calcium to Magnesium Ratio (Ca: Mg)

The minimum ratio of calcium to magnesium (Ca: Mg) in most soil of the project area is 1.96 while maximum is 5.23 with an average value of 3.43, which indicates that the value in most case is at optimum range for most crops.

4.2.10 Potassium to CEC ratio (K: CEC)

Two percent of K: CEC ratio suggests that a minimum level to avoid K deficiency and soils with more than 25 % ratio is considered to be potassium rich soil. Minimum potassium to Cation exchangeable capacity ratio of the soil unit in a project area was 0.001 and maximum was 0.065 with an average value of 0.014. Hence all the soil in the area under investigation has a ratio less than mean level which indicates that the soil of the study area was K deficiency in all profile.

4.2.11 Total Nitrogen (TN)

The total nitrogen is an indicator of the total amount of the different form of nitrogen such as organic nitrogen, NO₃, NO₂, and NH₄ ions. Apart from nitrogen fertilizer applications, the only other source of nitrogen in soil is the breakdown and humification of organic matter, and atmospheric nitrogen fixation by leguminous plants. This determination involved the well-known Kjeldahl method where the organic matter (containing nitrogen) is oxidized and nitrogen converted to ammonium. The ammonium is then estimated by titration against sulphuric acid. Results show that generally total nitrogen ranges from 0.11 to 0.37 percent which decreases from top to sub soil. The result shows that the total nitrogen of

the study area is high in the surface and low to medium in sub-surface of the profile.

4.2.12 Carbon to Nitrogen Ratio

The rate of decomposition of organic matter and the subsequent release (mineralization) or immobilization of soil nitrogen are both influenced by the carbon to nitrogen ratio of the organic material introduced to the soil. Nitrogen is released into the soil from the decomposing organic material if the organic material is added and it includes higher nitrogen relative to the carbon content. The soil nitrogen, on the other hand, will be immobilized and unavailable if the organic material has a lower proportion of nitrogen to carbon than is needed by the microbes for continued breakdown. A carbon nitrogen ratio of less than 10 is considered good, one of 10-15 is considered medium, and one of >15 is considered poor. The carbon to nitrogen ratio of the project area is in <10 and 10-15 for all soil which is in a good and medium carbon to nitrogen ratio.

4.2.13 Available Phosphorous

Phosphorous is present in soils in both organic and inorganic forms. The phosphorus availability to plants therefore differs between different forms of phosphorus in soils. The inorganic form is usually more important as a plant nutrient. Available phosphorus refers to the plant readily available form. The available phosphorus content of the soils of the project area varies from 0.00 to 17.77 ppm with average of 4.86 ppm which indicates that low level through out of the soil profile except high in some profile. Generally, the available phosphorus of the soil is rated as low and regarded as inadequate for crops development at existing condition.

4.2.14 Calcium Carbonate (CaCO₃)

The amount of carbonates present, the form of its distribution in the profile and the depth to the lime rich horizons are all important in the suitability evaluation of calcareous soils in irrigated agriculture. The presence of CaCO₃ affects both the physical and the chemical characteristics of a soil. Continuous horizons of carbonate accumulation may not restrict water movement severely, but may prevent root penetration. Discrete particles of carbonates also affect moisture characteristics and tend to create a less fertile environment for plant roots. A highly calcareous soil is less productive than slightly calcareous soil if all other factors are equal. Laboratory analyses of calcium carbonate result nil and there for there is no effect both on chemical and physical properties of soils. Field soil survey test with 10% HCL also show the soils of the project area is non-calcareous for most soils.

5. CONCLUSION

Based on the analysis results landuse systems have an impact on soil physicochemical properties. In that, well being of the soil is centred on physical and chemical characteristics. However, agronomic and other management activities need to be deployed so as to maintain the productive and health status of the soil. Already existing practices can be used to amend or correct the soil nutrient value with correctable limitations. This can be through application of phosphate and nitrogenous fertilizers and liming to raise the pH of the soils to near neutrality where most of the plant nutrients are available for plant up take. The overall Integrated Nutrient Management (INM) activities should be adopted for the study area for optimum and sustainable production of major crops.

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