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Assessment of Soil Nutrients and Agricultural Potential in Rare-site Forest Patch at Haramaya, Ethiopia: A Case Study on pH, EC, and Soil Characteristics

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Nutrients are a substance that promotes growth, provides energy, and maintains life. Any deficient nutrients will limit crop growth. Soil samples were collected from Rare-site inside forest patch in Haramaya University. Five sampling areas were identified inside the forest and the samples were collected at a soil depth of 0 to 20 cm by auger in systematic Zigzag sampling technique. The pH value of sample soil was 7.55, which was modestly alkaline. It was suitable for most of the plants to be grown, but slightly modifying the pH level may require when soil is used for agricultural crop production because salinity affects the upper parts of soil around the crops root. An estimated EC

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was 0.10065 ds/m. Though, the soils have a potential for agricultural development under rained as well as irrigated conditions, but the productivity is limited due to low fertility, low water holding capacity, shallow soil depth, prevalence of hardpan and faulty irrigation practices. The sample analysis revealed that the soil is undisturbed and good in condition of Total nitrogen, soil organic carbon and soil organic matter that was 3%, 4% and 65% respectively. The soil was loamy sand with 77%, 15% and 8% percent of sand, clay and silt proportion respectively. This implies that the water holding capacity was low and has high infiltration rate. Finally, the researcher have concluded that, the soil in this range does not require any significant modification for more production and sustainable agricultural development.

Keywords: Nutrients; pH; physicochemical; soil; TN.

1. INTRODUCTION

"Many countries throughout the world are facing acute scarcity of lands for food production due to the rapid increase of population and limited land resources, which causes people to convert forestland into agricultural, horticultural, plantations, and pastoral land for cattle settlements or mining" (P. Panwar and B. Sharma *et al*., 2011). "Such human activities have led to the depletion of existing forests throughout the world, particularly in Asian countries. In the tropics, approximately 60% or 850 million hectares of the total forest area between the year 1950 and 2000 have been degraded and are difficult to regenerate due to chemical, biological, and physical barriers" [1]. In 2019, some 34% of the land in Ethiopia was used for agricultural activities.

"Knowledge of soil science for the better understanding of the effective soil management and conservation is required for the rehabilitation of tropical rainforest on the land that is severely degraded. Consequently, a multivariate strategy can be implemented to measure the soil quality. Since properties of the same soil may respond differently to a degrading impact, it is expected to be more informative to quantify and integrate various soil variables than measuring a single variable" [2]. "A multivariate soil data set is regarded as integrated properties of the soil, integrating multiple soil physicochemical properties with the use of a multivariate statistical technique often provides new measures that explain variations among the soils" [3].

"Among soil physicochemical property, soil texture is a classification instrument used both in the field and laboratory to determine soil classes based on their physical texture. Soil texture can be determined using qualitative methods such as texture by feel, and quantitative methods such as the hydrometer method based on Stokes' law. In texture of soil there are composition of the soil regarding the amounts of clays (small), silts (medium) & Sand (large) particle size. Soils are the upper layer of earth, typically consists of loose mineral or organic materials, rock particles and clay in which plants grow. Particularly, soils are made up of about 25% air, 25% water, 45% mineral and 5% organic matter (i.e. plant residues, humus as well as living micro-organisms). Soil plays a vital role in degradation of soil, water transport processes (infiltration), controlling quality and productivity of soil, so that, soil texture is called as an important land environmental variable" [4].

"In a typical soil, there are three main components found those are sand, silt and clay. Soil texture is the most important property of soil and is determined by those three end members" [5].

For sustainable agriculture management and quality assessment of soil, the texture of soil (i.e. Sand, silt, clay) is one of the key indicators. For agricultural growth, the soil texture is considered as an important environment factor. Now-a-days, various stakeholders including soil scientists, environmental managers, land use planners and traditional agricultural user's demands for the precise soil information in large scale.

Plant nutrients are the chemical elements that are essential to the nourishment of plant health. The role of plant nutrients in crop production is well established. There are 16 essential plant nutrients. These are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), Sulphur (S), zinc (Zn), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo) and chlorine (Cl). These nutrient elements have to be available to the crops in quantities as required for a yield target. Any limiting or deficient nutrient (or nutrients) will limit crop growth.

Accurate and timely analysis helps in determining the requirements of plant nutrients so as to arrange their supply through various sources. The analytical facilities required for chemical analysis of soils, plants, water and fertilizers are broadly identical in nature with a few specific requirements in terms of facilities and chemicals for certain estimations. The facilities for bio fertilizer analyze are of a highly specialized nature and are different from those required for chemical analysis. In view of this, it is possible to set up integrated facilities for soil, plant, water and fertilizer analysis, and a bio fertilizer testing facility can be added (as appropriate) in an adjacent or expanded building. A common facility saves on supervision and other costs, such as common equipment and chemicals. Though, it was aimed to determine the nutrients of physicochemical properties of forest soil.

2. MATERIALS AND METHODOLOGY

2.1 Sample Collection and Preparation

Soil sample was collected from Rare-site inside forest patch in Haramaya University. Sample collection was done based on the information obtained from laboratory assistance in scientific method of soil sample collection for physiochemical analysis. Therefore, five sampling spot areas were identified inside the forest area. The soil samples were collected by auger at a soil depth of 0 to 20 cm using systematic Zigzag sampling technique. The collected soil samples were composited and inserted in to the plastic bags with labeled for easily identification and took to the soil sample processing class and drying in air for four days. After drying, the soil sample were grinded (crashing) and passed through 2 mm and 0.5 mm for determination of soil physiochemical analysis in laboratory.

2.2 Main Apparatus used

Main materials were used for sample collection during our work were: Auger, Plastic bag, Sieve, Sensitive balance, Biker, Striker, pH-meter, Filter funnel and measuring cylinder, Volumetric flask, Flame photometer and Spoon.

2.3 Determination of Soil PH, Organic Carbon, Exchangeable Base and Texture

“Soil pH is a measure of the acidity or alkalinity of a soil. The term pH applies to solutions, so the analysis were conducted on a soil/water mixture. There are several factors affect pH measurement. Soil reaction (pH) and electrical conductivity (EC) were determined from saturated paste extract. Soil pH were measured potentiometrically using a digital pH-meter and EC by digital conductivity meter according to the method outlined by the” [6]. “Organic carbon was analyzed by wet oxidation with potassium dichromate (K2Cr2O7) in a sulfuric acid medium” [7]. Percent of organic matter content of the soils were estimated by multiplying the value of percent organic carbon by the conversion factor of 1.724, according to the assumption that organic matter is 58% carbon, that has been used for converting measurements of soil OC into estimates of soil OM. The total nitrogen (N) content of the soil were determined indirectly by dividing OM% by 20 (%OM=%TN X 20). Exchangeable basic cation (Ca, Mg, K and Na) were determined by saturating several times the soil samples with 1 M·NH4OAc solution at pH 7.0. Exchangeable Na and K were measured by flame photometer from the same extract. The amounts of these nutrients in the extracts were determined by atomic absorption spectrophotometer. The soil texture were determined by using sedimentation techniques; the settling rates of dispersed particles in water are measured. Large particles are known to settle out of suspension more rapidly than do small particles.

2.4 Main Procedures

2.4.1 pH of the soil

Main procedures to test soil pH were weight 10 gm. of soil sample by sensitive balance and then add 25 ml of distilled water by using biker that must strike for 1 minute by striker through waiting for 25 minutes for Cation suspensions and finally, test soil pH by using pH-meter**.**

2.4.2 Organic carbon

Main procedures to test organic carbon were: weight 1gm of soil sample then add 15 ml 1normality $K_2Cr_2O_7$ and 20 ml concentrate H_2SO_4 then Wait for 20 minutes (until the reaction is completed) and add 200 ml of distilled water,10 ml concentration H_3PO_4 and 4 drops of barium diphenylamine sulphate and finally, titration by Fe_2SO_4 (0.5 Normality).

2.4.3 Soil texture

Main procedures to test soil texture were: weight 50 gm. of soil and add 100 ml dispersing reagent and finally, wait for 10 minutes for string.

2.4.4 Exchangeable base

Main procedures to test exchangeable base were: weigh 5 gm. soil sample, then transfer to a filter funnel placed on 100 ml volumetric flask then wash four times each with 25 ml of 1morality at pH-7 of Ammonium acetate solution and then, remove the VF and bring up to volume with distilled water and finally, read the leachate by flame photometer.

3. RESULTS AND DISCUSSION

3.1 Determination of Soil pH and EC

The soil pH and EC levels within the substrates are highly important for optimal plant growth. The pH value of sample soil were 7.55, which was moderately alkaline. In this range of pH was commonly called a calcareous soil [8]. It is suitable for most of the plants to grown, but slightly modifying the pH level may require when soil is used for agricultural crop production because of salinity affects the upper parts of soil around the crops root. Soil with a pH between 6.5 and 8.0 rarely needs to be acidified capacity [9]. The other way to maintain the productivity of alkaline soil was selection of crop types and variety that well grown in this pH range. Most cereal and horticultural crops were grown well in this pH range; whereas there are different treatment options to lowering the pH of alkaline soil. The soil with pH 7.55 requires only elemental sulfur to lower pH, but fertilizers as acidifying materials also used to lowering the alkaline. Ammonium-containing fertilizers can acidify soil. The fertilization process is slower when compared to acidification by elemental Sulfur. In this example, 10 years of ammonium containing fertilizer applications were necessary to attain the same degree of acidification as that achieved with a single application of elemental Sulfur. addition of gypsum (calcium sulfate) were identified to lower soil sodium content which has greater than pH value of 8.5, but in our sample case not yet needed at all. Irrigation water quality, particularly bicarbonate content will increase chlorosis and the need for acidification [10]. Field bund, land shaping, construction of irrigation channel, construction of peripheral bunds, sluice gate, farm ponds/water harvesting structure, construction of surface/sub-surface drainage as per need of the area, green manuring & its mulching into soil for increasing organic carbon and as well as suitable to grow crops. The salinity of soil can be estimated roughly from an electrical-conductivity measurement on a saturated soil paste or a more dilute suspension of soil in water. An estimated EC was 0.10065 ds/m. Though, the soils have a potential for agricultural development under rained as well as irrigated conditions, while the productivity was limited due to low in soil fertility, lower water holding capacity, shallow soil depth, prevalence of hardpan and faulty irrigation practices. Measuring the pH of soil gives you an idea of how available the nutrients are, while EC clues the actuality.

$EC = \frac{\text{CS}}{\text{tf}}$ $EC = \frac{1 \times 9.23}{0.917}$, =10.065/cm convert to desi semen= 0.10065 ds/m

Table 1. Sample analysis

Sample code	Start	End	Difference
Blank (VB)	0	17.6	17.6
Group -2	0	16.4	16.4

3.2 Organic Carbon, Organic Matter and Total Nitrogen

Soil organic carbon (SOC) is a measureable component of soil organic matter. Organic matter makes up just 2 to 10% of most soils mass and has an important role in the physical, chemical and biological function of agricultural soils. Organic matter contributes to nutrient retention and turnover, soil structure, moisture retention and availability, degradation of pollutants, and carbon sequestration. It refers only to the carbon component of organic compounds. Here also, soil organic matter (SOM) is very important aspect for management of soil. It is difficult to measure directly the SOM, so laboratories tend to measure and report soil organic carbon. Sequestering carbon in SOC was seen as one way to mitigate climate change by reducing atmospheric carbon dioxide. SOM is composed mainly of carbon, hydrogen and oxygen, and has small amounts of other elements, such as nitrogen, phosphorous, sulfur, potassium, calcium and magnesium contained in organic residues. It is divided into ‘living’ and ‘dead’ components. This implies that the living component includes soil macro- and micro-fauna, and soil microbial communities, which may be active or dormant. The non-living portion of soil organic matter is derived from dead plant and faunal inputs into the soil.

Table 2. Hydrometer and Temperature reading

Hydrometer reading		Temperature reading	
H1	H2	T1	T2
40 second	2 hour	40 second	2 hour
12.5	5	23	22

"Total Nitrogen of the soil have estimated by multiplying average value of C: N ratio= 20% of SOM. By incorporating SOM conservation into management plans, farmers and producers sequester atmospheric carbon and benefit from an overall increase in soil quality and possibly lower input costs" [11]. In our soil sample, the result revealed that the soil was undisturbed and had a good condition of SOC, SOM and Total nitrogen that is 4%, 65% and 3% respectively. The laboratory results of OC, OM and TN were explained [12].

3.3 Soil Texture

"As soil particles are freely settling down the water column, they are sorted according to particle size. Coarse particles, like sand, move down faster than fine particles. Because of their differential settling rate in water, the size fractions are sorted into different size ranges" (Amazirh, 2021). That is why the sample down faster in H1 than H2 during our lab work. The soil was loamy sand soil with 77%, 15% and 8% percent of sand, clay and silt proportion respectively. This implies that the water holding capacity is low and has high infiltration rate. Therefore, application of irrigation for plant growth through long period at slow flow rates of water were suggested. The detailed data were calculated as presented.

Calculated result of soil texture:

No	Sand %	Clay %	Silt %
1	77	8	15

3.4 Exchangeable Base

Exchangeable bases are important for determination of soil fertility status. Ideal exchangeable base for crops are very important. Soils with high base saturations are considered more fertile because many of the "bases" that contribute to it are plant nutrients. Potassium (K) and Sodium (Na) are not an essential element for plant growth required in large amount, but it is important for diagnosing problematic soils. Some study shows the ideal level contain 2 to 4 for potassium and less than 1% for sodium and other 2 to 5 and 1 to 2% for K and Na respectively (Hill Laboratory report).

In our soil test, the result has showed that it was above ideal level of potassium (K) and sodium (Na) which were 9.6 and 3.26% respectively. The reason may be parent soil characteristics or low rainfall to leach the exchange base. In soils with high soil sodium levels, the soil may contain natural deposits of this element. The soil analysis and calculation to estimate the exchangeable base (K and Na) were explained.

K- Standard for calculation (calculate- K):

X	Y
0	0
2	21
4	41
6	60
8	80
10	102

Results of calculated potassium:

K absorption	K blank	Exchangeable k	Remark
1.9593	0.0756	0.9657	

To calculate Sodium (Na):

X	Y
	0
	23
8	48
12	62
16	86
20	100

Results of calculated sodium (Na):

Na absorption	Na blank	Exchangeable Na	Remark
6.183	-0.1896	0.3267	

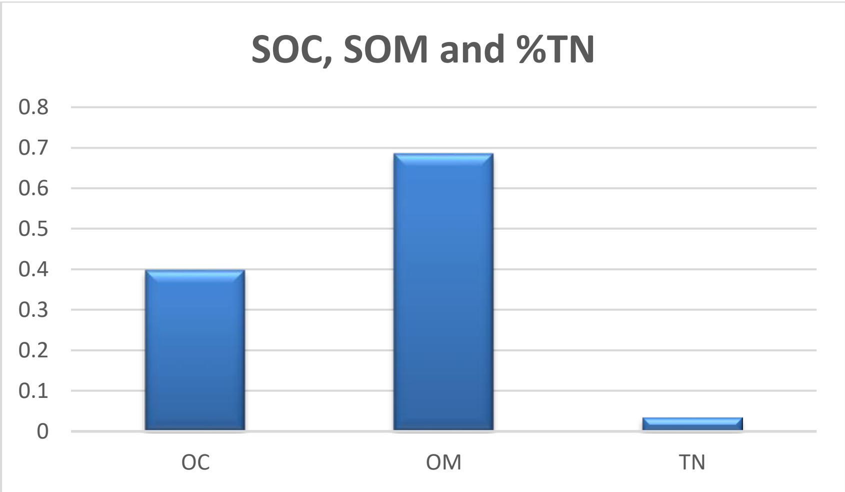

Fig. 1. Results of SOC, SOM and %TN

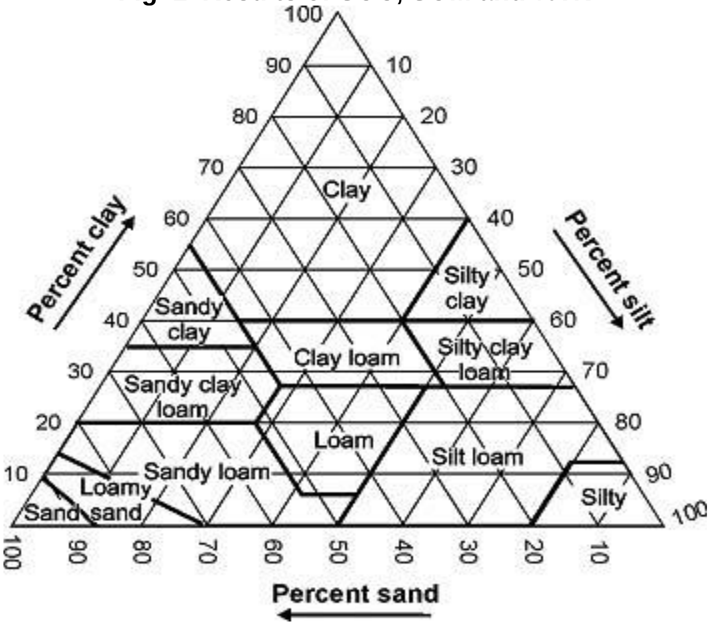

Fig. 2. Soil texture analysis

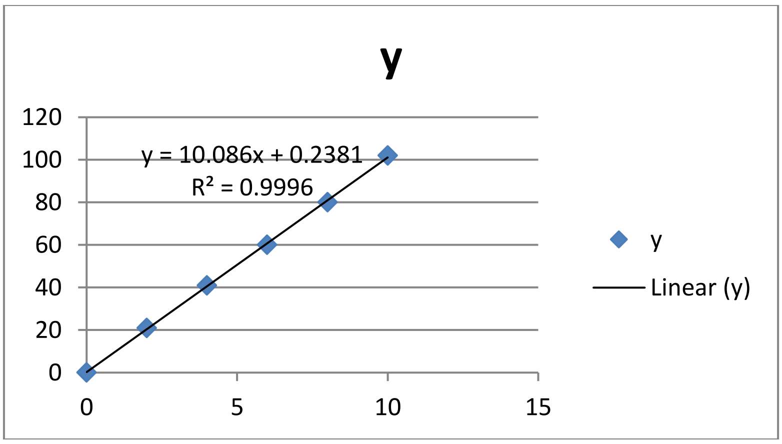

Fig. 3. K- Standard for calculation (calculate- K)

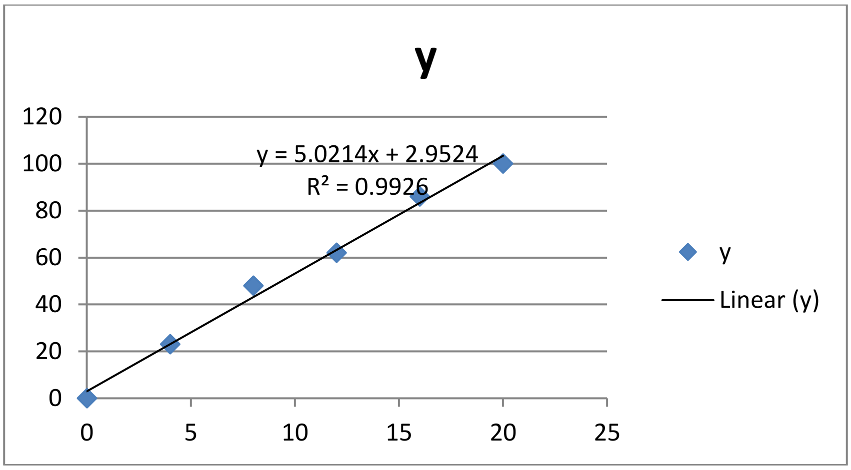

Fig. 4. K- Standard for calculation (calculate- Na)

4. CONCLUSION

The soil sample were collected and analyzed in the laboratory for the assessment of soil nutrient status and physicochemical properties of the soil. The soil pH, EC, soil organic matter, organic carbon, Total nitrogen, soil texture and exchangeable base (Na and K) were determined. The pH value of sample soil was 7.55, which was modestly alkaline. The majority of the plants could grow there, but since salinity affects the upper soil near the roots of the crops, it could be necessary to slightly adjust the pH level when using the soil for agricultural crop development. An estimated EC was 0.10065 ds/m. Even though the soils have the ability to support agricultural growth in both wet and dry situations, their productivity is constrained by factors like poor fertility, low water-holding capacity, shallow soil depth, the presence of hardpan, and improper irrigation techniques. The sample analysis revealed that the soil is undisturbed and good in condition of Total nitrogen, soil organic carbon and soil organic matter that was 3%, 4% and 65% respectively. The soil was loamy sand with 77%, 15% and 8% percent of sand, clay and silt proportion respectively. Generally, all soil analysis were revealed that the soil needs only minimum treatment because the soil has a moderate alkaline in pH and slight in exchangeable base. Finally, it can be concluded that the soil needs very slight treatment because it does not affect the trees in this range.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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