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Measurement of Soil Particle Size Distribution Using Hydrometer Analysis

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Abstract: The soil particle size distribution of the study area was determined using hydrometer techniques at Holetta agricultural research center. The soil sample used was taken from the nitosol of the Holetta agricultural research center. The soil separates were divided into sand, silt and clay according to the size of the particles. The laboratory analysis of soil particle size distribution indicated that clay was the dominant soil particle (65.00%) followed by silt (18.75%) and sand (16.25%) in the study area. The soil of the study area was assigned to a clayey soil textural class based on the soil textural triangle of the united states department of agriculture. The soil particle size distribution is an important parameter in soil classification and has implications for soil water, aeration and nutrient availability to plants. Pore spaces are the spaces that exist between soil particles (clay, silt and sand) and between and within clusters of soil particles (aggregates). They are the portion of the soil occupied by air and water. The number, size and shape of pore spaces are determined by the size of the soil particles (soil texture) and the arrangement of the soil particles into aggregates (soil structure). The larger pores (macropores) allow air and percolating water to move easily through the soil while the smaller pores (micropores) don't allow air to move easily and also largely limit water movement. In sandy soil little water can be stored due to large pore sizes and irrigation will thus have to take place frequently but little water is given per application. In loamy soil, more water can be stored due to intermediate pore sizes than in sandy soil and irrigation water is applied less frequently and more water is given per application. The pore spaces in clayey soils are too small which are filled with a very thin film of hygroscopic water that does not allow good aeration or infiltration of water through the profile and the water is unavailable to plant roots. A mixture of large and small pores and the relative amounts of solids, air and water in the soil is very important for good plant growth. So, soils that have a good balance of particle sizes will have the best balance of pore space size and thus will have the best soil properties for maximum plant growth and productivity. Generally, the soil of the study area is clayey soil which is very fertile but unproductive due to high water holding capacity, particularly in the peak rainy season. However, the productivity of the soil can be enhanced through draining excess water and applying compost and/or farmyard manure. Due to the high water holding capacity of this soil, irrigation water is applied less frequently but more water should be given per application as compared to loamy and sandy soils when irrigation practice is employed by farmers in the study area.

Key words: Clay · Hydrometer · Particle Size Distribution · Sand · Silt · Soil Structure · Soil Texture

INTRODUCTION

Particle size distribution (PSD) is one of the most important soil parameters often used in soil, geological and geo-morphological laboratories [1-3]. It refers to the determination of the range of particle sizes that make up the soil [4]. The wide use of PSD can be confirmed by the fact that knowledge of PSD is needed to determine the physicochemical processes occurring in the soil [5, 6], pedotransfer functions [7, 8], fractional dimension [9, 10]

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and microbial activity [11, 12]. The PSD is usually expressed as a percentage of total mass and is one of the most fundamental physical properties of a soil, defining, for example, the soil's texture and strongly affecting many physical and chemical soil properties [13]. Past studies suggest that changes in PSD can provide useful indications on the influences of land use, soil degradation and desertification processes on soils [14-16]. PSD is expressed as a mass percentage of clay, silt and sand. The USDA classification of soil texture is based on the proportion of sand 2.0-0.05 mm, silt 0.05-0.002 mm and clay < 0.002 mm particles [17]. These three fractions are used as predictors of important soil properties such as water retention curve, available water capacity, saturated hydraulic conductivity, thermal conductivity and adsorption properties of chemicals [18-20]. Particle size distribution analysis (PSDA) is a measurement of the size distribution of individual soil/sediment particles, sand, silt and clay, which can be used to understand soil genesis, to classify soil or to define texture [21].

Soil mechanical or particle size analyses (PSA) are needed to relate soil texture to soil performance or behavior. Particle size analysis refers to the determination of the range of particle sizes that make up the soil. There are two main techniques of soil PSD measurements: sieve-sedimentation (SSM) and laser diffraction methods (LDM). Among the many varieties of sieve-sedimentation methods, the most commonly used are the pipette [22] and the hydrometer methods [23]. Smaller particles are usually determined by sedimentation using hydrometer or pipette methods [24]. These methods are time-consuming and require careful attention to sampling procedures to ensure correct sampling time, solution temperature, etc. Recent advances in instrumentation have led to the development of devices that measure the distribution of particles using LDM [25]. Using a small sample, these devices can provide relatively easy, rapid and highly reproducible way of determining the fraction of total volume- or weight-fractions of particles for a large number of size classes [26]. However, this method bears some inadequacy, compared with the results of sedimentation methods [27, 28], for instance, underestimation of the clay fraction has been reported [29]. Bouyoucos [30] proposed the hydrometer, which is less accurate than the pipette method but also simpler and quicker to use, as an alternative analytical method. Both methods are based on Stokes' law [31], which establishes a relationship between particle size and the rate of sedimentation. Thus, particles are assessed by their setting velocities from suspension in a water solution that can be used to quantify particle size. Therefore, the objective of the current study was to measure the distribution of different sizes of soil particles in nitosol using hydrometer techniques at Holetta agricultural research center.

MATERIALS AND METHODS

Description of the Study Area: The soil sample was taken from Holetta Agricultural Research Center (HARC) during the main cropping season of 2019 and tested at the HARC soil laboratory. The center is located at 9°800'N latitude, 38°30'E longitude at an altitude of 2400 m above sea level. It is 34 km west of Addis Ababa on the road to Ambo and is characterized with the long term (30 years) average annual rainfall of 1055.0 mm, the average relative humidity of 60.6%, and average maximum and minimum air temperature of 22.2°C and 6.1°C, respectively [32]. The rainfall is bimodal and about 70% of the precipitation falls in the period from June to September, while the remaining thirty percent falls in the period from March to May [33]. The soil type of the area is predominantly red nitosol, which is characterized by an average organic matter content of 1.8%, total nitrogen 0.17%, pH 5.24 and available phosphorus 4.55ppm [34]. The farming system of the study area is mixed crop-livestock production where tef is the main staple crop complemented by other cereals such as barley and Wheat. Map of the study area is indicated in Figure 1.

Soil Sampling and Preparation: Soil samples were collected from Holetta Agricultural Research Centerduring August 2019. The soil sample was taken from nitosol which is the dominant soil type in the study area. Three soil samples were taken randomly from the experimental field using augur to the depth of 0-30 cm from the topsoil layer [35]. The sampled soils were composited into a bucket. Crumbs of the soil were broken into small pieces and thoroughly mixed. From this mixture, a sample weighing 1 kg was filled into an airtight polythene bag. Then the sample was labeled and brought to Holetta agricultural research center for laboratory analysis. Larger particles and other debris were removed from the soil and then soil samples were air-dried in a dry and dust-free place at room temperature (25°C) for 5 days, followed by oven drying for 24 hours in 105°C until getting constant weights.The air and oven-dried soil sample was well mixed and ground with mortar and pestle to pass through a < 2 mm sieve and homogenized.

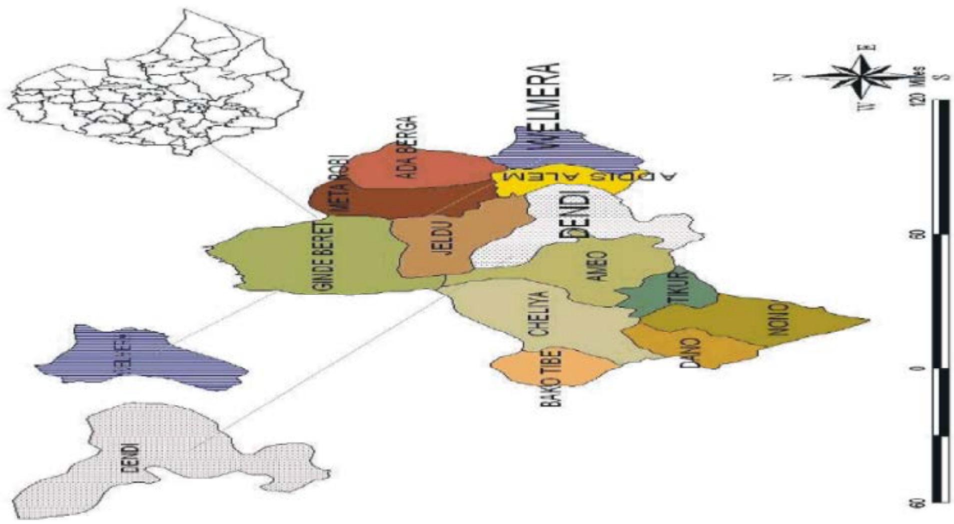

Fig. 1: Map of the experimental site, at Holetta (Welmera) in the central highlands of Ethiopia

The dried, sieved and the homogenized working sample obtained from the submitted sample was placed in a polyethylene bag, properly labeled and submitted to Holetta research center soil and plant testing laboratory for analysis of particle size distribution following the standard laboratory analysis methods.

Soil Sampling Analysis

Apparatus Used for Analysis: The common laboratory apparatus which were used during the study include; different sized beakers, graduated cylinder 1000ml, hydrometer with bouyoucos scale in g/L (ASTM), a high-speed electric stirrer with a cupreceptacle, thermometer -10 to 100°C, plunger, plastic wrap, soil dispersing stirrer, squirt bottle for washing soil out of the beaker, Spoon, glass rod for mixing, stopwatch, vinyl gloves, steelless steel auger, polyethylene bags, oven, sieve, distilled water and analytical balance.

Chemicals and Reagents: Sand, silt and clay particles are rarely found separately in soils. Instead, they are usually clumped together in aggregates called "peds." A "dispersing" solution is used to break up the peds and separate the particles from each other. Therefore, the Calgon dispersion solution was prepared by mixing 40 grams of sodium hexametaphosphate $(NaPO_3)_6$ and 10 grams sodium carbonate (Na_2CO_3) in 1 literdistilled water. Moreover, 30% of hydrogen peroxide (H_2O_2) was used as a dispersing agent of organic matter available in the soil [24].This solution was stirred until the dispersing agent had completely dissolved.

Particle Size Analysis (Mechanical Analysis): Soil texture analysis was determined using the bouyoucous hydrometer method [36]. A hydrometer (calibrated in g/L) measures the specific gravity of a liquid or suspension. Specific gravity is defined as the mass of a liquid relative to the mass of an equal volume of water. In pure distilled water at 20°C, the hydrometer reading will be 1.000. When the soil is suspended in the water due to high specific gravity, the hydrometer reading increased. To measure the specific gravity of the soil/water suspension, the hydrometer is placed in the soil suspension 45 seconds before the reading is to be made to allow the hydrometer to become still in the water. At the appointed time (at 2 minutes and again at 24 hours), the hydrometer is read at the level where the number scale touches the surface of the water.

Weigh 40g of dried, sieved (<2mm) soilsample and pour itinto 600ml beakers. Add 50ml of the dispersing solution (5%Calgon solution) and 25ml of distilled waterto the beaker.The prepared water–soil slurry was stirred vigorously with a stirring rod for at least 5 minutes as a result the soil was thoroughly mixed and did not stick to the bottom of the beaker. Proper care was taken for soil suspension which spill out the top of the beaker due to the stirring process and rinsed any soil off the stirring rod into the beaker using a little distilled water. Then the top of the beaker was securely covered with plastic wrap and left overnight. After 24 hours, the water–soil slurry was transferred to the cup and put the cup on a Humboldt mixer to mix thoroughly for 5 minutes. Then the slurry was transferred into a 1000 ml graduated hydrometric jar.

A squirt bottle was used to rinse all soil out of the cup and into the hydrometric jar. The mixture was mixed with a special plunger at least 20 times. Then the plunger has rinsed all soil into the hydrometric jar and the jar filled up to 1000 ml mark using distilled water.

The hydrometric jar was gently set down in a safe place and immediately begun timing with a stopwatch. After 2 minutes, carefully immersed the hydrometer into the jar and allowed it to float in the soil suspension. Carefully steady the hydrometer to stop its bobbing motion and then read the line on the hydrometer that is closest to the surface of the soil suspension after 45 seconds. After the reading was taken, the hydrometer removed, rinsed it away from the jar, dried it and gently put it down in a sedimentation 1000 ml cylinder filled with deionized water and 50 ml of 5% Calgon solution (blank solution) and taken a Bouyoucos hydrometer reading and determined the temperature of the solution. On the other hand, suspend the thermometer in the suspension for about 1 minute. At the end of a minute, the thermometer was removed from the suspension and the temperature reading was taken and rinsed the thermometer off and dried it. The jar was kept undisturbed for 3 hours and the second hydrometer and temperature readings were taken. Finally, the soil suspension was discarded by pouring it into a special pail and spilled the contents outside in a special place for discarding soil materials.

Blank was a sample that does not contain any (or a negligible amount of) analyte. The blank was used to assessing the degree of contamination in any step of the measurement process. It was also be used to correct relatively constant, unavoidable contamination. The method blank accounts for contamination that may occur during sample preparation and analysis. These could arise from the reagents, the glassware, or the laboratory environment. Hence, it can be concluded that the analytical method was free of overall laboratory contamination [37]. If the temperature is greater than 20°C then add the established temperature correction factor for each temperature level, but if the temperature is less than 20°C subtract it (Table 1). Moreover, the reading of the blank should be subtracted from both readings. The amounts of sand, silt and clay are measured according to the rate at which each particle type settles in water. The result is reported as % clay, % silt and % sand. The calculation was done using the following formula.

$$\%Clay + Silt - 1^{st}\, R - B(\pm T)x\frac{100}{Wt}\ \textit{from the first reading}$$

$$\%Clay = 2^{nd}\, R - B(\pm T)x\frac{100}{Wt}\ \textit{from the second reading}$$

$$\%Sil = \%(Clay + Silt) - Clay$$

$$\%Sand = 100 - \%(Clay + Silt)$$

where: R= Hydrometric reading, B= Blank, T= Temperature, Wt= Weight of soil sample used for analysis.

Table 1: Temperature correction factor

Temperature (°C)	Correction factor
15	-2.0
16	-1.5
17, 18	-1.0
19	-0.5
20	0
21	+0.5
22, 23	+1.0
24	+1.5
25	+2.0

RESULTS AND DISCUSSION

The hydrometer technique was used to determine the soil particle size distribution of nitosol taken from the Holetta Agricultural research center in August 2019. The dried and sieved soil sample was mixed with water and a dispersion solution was used to completely separate the particles from each other. The prepared soil-water slurry was thoroughly stirred to fully suspend the soil in the water. When a soil sample was stirred, sand particles settled to the bottom of the cylinder after 2 minutes, while the clay and silt size particles stay in suspension. However, the silt particles settled after 24 hours, leaving only the clay in suspension and the specific gravity and temperature of the suspension were measured using a hydrometer and thermometer. The major parameters collected from soil-water slurry and the blank solution for determination of soil particle size distribution are indicated in Table 2. The first hydrometer reading was 36 and 2 g/l for soil-water slurry and blank solution, respectively. On the other hand, the second hydrometer reading showed 31 g/l for soil-water slurry and 4 g/l for a blank solution. The temperature records for the first and second readings were 19.5 and 18.5°C, respectively. Using the collected parameters, the particle size distribution of the soil of the study area was determined.

Soil can be described by the relative abundance of solid primary particles it contains. These particles, depending on their size, can be classified as sand, silt, or clay and these particles influence many soil physical properties such as water-holding capacity and drainage [38]. The relative proportion of sand, silt and clay in the soil is known as soil texture [4]. These particles are categorized by their sizes, with sand particles being the largest. Generally, sand particles range from 0.05 to 2.00 mm in diameter; silt particles range from 0.002 to 0.050 mm; and clay particles are smaller than 0.002 mm [39]. They are commonly identified as coarse-textured soils, medium-textured soils and fine-textured soils, respectively. Soil particle size distribution calculation and the relative proportions of sand, silt and clay particles of the sampled soil from the study area are indicated in Table 2. The result indicated that the proportion of clay was the dominant soil particle followed by silt and sand. Other research findings also indicated that clay is the dominant soil type of the study area [40, 32].

The soil separates were divided into sand, silt and clay according to the size of the particles. Particle size distribution (soil texture) is an important parameter in soil classification and has implications for soil water, aeration and nutrient availability to plants [20, 41]. The particle size distribution of the sampled soil was determined by laboratory analysis as indicated in Table 4. The result showed that the highest proportion of 65.00% was recorded for clay particles followed by silt (18.75%) and sand (16.25%) particles. The clay content of the soil in the study area was generally very high when compared with the other soil particles. Coarse textured soils have mainly large particles in between which there are large pores while fine-textured soils have mainly small particles in between which there are small pores. Coarse soils, like sandy soils, consisting of large particles, leave ample space between particles (macropores), whereas fine soils, like clay soils, consisting of smaller particles, mostly form micropores [42]. Soils with a high proportion of sand are referred to as 'light' and those with a high proportion of clay are referred to as 'heavy'. When they are wet, sandy soils feel gritty, silty soils feel smooth and silky and clayey soils feel sticky and plastic, or capable of being molded.

Because there can be an infinite array of percentages of sand, silt and clay in soils, a scientist has devised a procedure for classifying the potential combinations into 12 groups that reflect broad soil properties. These groups are called textural class names and are obtained by applying the particle size analysis to a textural triangle. The textural triangle was used to determine the textural class of the soil sample. The soil was assigned to a textural class based on the soil textural triangle of the United States Department of Agriculture

Table 2: Basic parameters collected during laboratory analysis to determine soil texture

SN	Parameters	Soil-water slurry	Blank solution
1	Lab number	2606B	2606
2	Weight of sample (g)	40	--
3	First hydrometer reading	36	2
4	First reading time (mm/hr)	5:11	5:09
5	First reading temperature (°C)	19.5	19.5
6	Second hydrometer reading	31	4
7	Second reading time (mm/hr)	8:16	8:14
8	Second reading temperature (°C)	18.5	18.5
9	Silt (%) + Clay (%)	83.75	--
10	Clay (%)	65.00	--
11	Silt (%)	18.75	--
12	Sand (%)	16.25	--

Table 3: Soil texture determination using hydrometer technique

SN	Texture	Calculation and result	
1	% Clay + % Silt	Formula	$(1^{st}$ R-B±T°)*100/40
		Calculation	(36-2-0.5)*2.5
		Result	83.75%
2	% Clay	Formula	$(2^{nd}$ R-B±T°)*100/40
		Calculation	(31-4-1)*2.5
		Result	65.00%
3	% Silt	Formula	(%Clay + %Silt)-%Clay
		Calculation	83.75-65.00
		Result	18.75%
4	% Sand	Formula	100%-(%Clay + %Silt)
		Calculation	100%-83.75%
		Result	16.25%

Table 4: Soil texture

SN	Texture size	Soil texture	Proportion (%)
1	Coarse	Sand	16.25
2	Medium	Silt	18.75
3	Fine	Clay	65.00

Table 5: Soil textural class

% Sand	% Silt	% Clay	Soil textural class
16.25	18.75	65.00	Clay

[17]. The texture is determined by drawing lines from the percentage point on the relevant axis parallel to the side of the triangle at the zero ends of the same axis. Where the 3 lines intersect indicates the soil texture. Using the textural triangle and the particle size distribution of sand, silt and clay, the soil textural class of the study area is clay (Table 5). To determine the textural class firstly, the ruler was placed along the base of the textural triangle at the 16.25% sand mark and drew a line. Secondly, the edge of the ruler was also placed along the right side of the textured triangle at 18.75% silt mark and drew a line. Thirdly, the point where the two lines crossed was marked and using the ruler this point was matched with the 65.00% clay from the sample. Finally, the textural class of

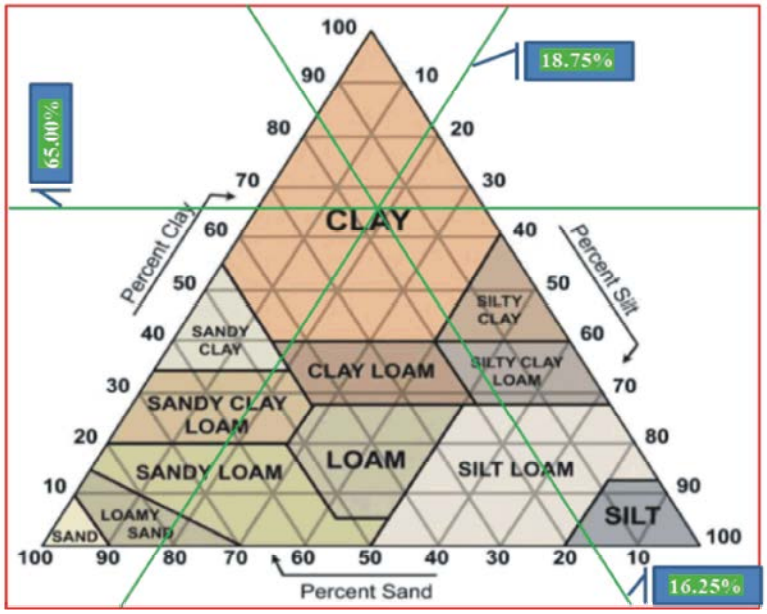

Fig. 2: Determination of soil textural class using the textural triangle method

the sample was determined to be clay by reading the class name where the three drawn lines met (Figure 2). The soil texture triangle indicated that the soil of the study area was clay soil. The texture of the soil in the field is not readily subject to change, so it is considered a permanent soil attribute [43]. Since "these components of soil are largely unalterable, there's not much you can do to change them" [44]. Therefore, according to Berry *et al*. [45] "It is very impractical (expensive) and thus ill-advised to modify a soil's texture." However, related impacts can be mitigated through appropriate agricultural practices.

The particles classified as silt are intermediate in size and chemical and physical properties between clay and sand. The silt particles have limited ability to retain plant nutrients or to release them to the soil solution for plant uptake [51, 52]. If the silt content is 30–40%, it provides a good loamy condition, which favors optimum water holding capacity and optimum drainage but it causes poor drainage when the silt content is > 40%. Silt tends to have a spherical shape, giving a high silt soil a soapy or slippery feeling when rubbed between the fingers when wet and is more difficult to form into a string than clays. Because of the spherical shape, silt also retains a large amount of water, but it releases the water readily to plants [46]. While silt soils are generally considered very fertile for the growth of plants, largely due to their water characteristics and ease of cultivation and lack of ability for the particles to stick together. Water displaces air in the soil and consequently, the air content of a soil is inversely related to the water content. High water content in soils means there is less air within the soil. This results in higher levels of carbon dioxide and lower levels of oxygen within the soil which is not favorable for plant growth.

Clay size particles are the source of most of the chemical properties of soil. They are responsible for the retention of many of the plant nutrients in the soil [53-56]. Clays react with the breakdown products of organic matter to stabilize the humus in the soil. A soil without clay particles can be very infertile soil. Clay is the most active fractions of soils and greatly determines the ability of the soils to hold H and Al ions on their colloidal surface [57]. Clays, because of their very small size and very large surface area, can retain greater amounts of water than sandy soils [46]. On the other hand, clays hold the water more closely and do not release the water as readily to roots as sands. The clay content should be < 50% for irrigated crops. If clay content is more than this, it will lead to poor drainage and stagnation of water, poor gaseous exchange and high water holding capacity. In fine soils, the high adsorptive and capillary forces resulting from high specific surface area and smaller intra-particle pore space allow holding and storing water within the soil. In this respect, clay is an important soil fraction because it has the most important influence on such soil behavior as water holding capacity. Clay particles have a vastly greater tendency to stick together than sand, thus it is common farmer knowledge that soils high in clay are difficult to till. When a small sample of clay soil is wetted and rubbed between the fingers it will feel very sticky and is easily formed into a string. Soil texture may limit which crops can be grown. For example, root crops, such as carrots and onions, perform best in sandy soil because it is loose and allows the plant to expand. However, the growth of some plants is stunted when growing in sandy soils because they lack the water- and nutrient-holding ability.

The texture is one of the most important properties of soil and it greatly affects crop production, land use and management. The type of clay present and the proportions of the different-sized particles sand, silt and clay which also have important effects on soil texture [58]. When dry soil is crushed in the hand, it can be seen that it is composed of all kinds of particles of different sizes [59- 62]. The water infiltrates faster (higher infiltration rate) when the soil is dry than when it is wet. As a consequence, when irrigation water is applied to a field, the water at first infiltrates easily, but as the soil becomes wet, the infiltration rate decreases. The soil type influences the maximum amount of water, which can be stored in the soil per meter depth. Sandy soil can store only a little water or, in other words, sandy soil has low total available water (TAW) content. On sandy soils, it would be necessary to irrigate frequently with a small amount of water. On the other hand, clayey soil has high TAW content. Therefore larger amounts of irrigation water can be applied to clayey soils, but less frequently. The root depth of a crop also influences the maximum amount of water, which can be stored in the root zone. If the root system of a crop is shallow, little water can be stored in the root zone and frequent but small irrigation applications are needed. With deep-rooting crops, more water can be taken up and more water can be applied, less frequently. Young plants have shallow roots compared to fully-grown plants. Thus, just after planting or sowing, the crop needs smaller and more frequent water applications than when it is fully developed.

Soil is a porous material consisting of particles of different sizes touching each other but leaving spaces in between. These spaces, which are not occupied by the soil particles, are known as pore space. It constitutes about 40 to 60% of soil on a volume basis. It provides space for water and air circulation and it plays a vital role in irrigation management. There are two types of pore spaces *viz.*, micropore and macropore. There is no sharp line of demarcation between the macro and micropores. The macropores allow the ready movement of air and permeability of water freely while in the micropore air movement is greatly difficult and water movement is restricted to slow capillary movement [63]. The volume of pore spaces varies according to the soil texture. Soils having big particles contain less pore space than those having small particles. Thus the volume of pore space in an enclosed container having big particles is less than that of small particles. The size of individual pores is highly important for the movement of water in soil than the percentage of total pore space in the soil. For example, the percentage of pore space is high in clay soil, which contains more micropores where water movement is highly restricted and thereby water-holding capacity is more. In sandy soil, the percentage of pore space is relatively less than clay soil, but it contains a large number of macropores. Hence, the water movement is free.

Porosity, the specific surface area of soil particles and pore size distribution of soil properties are influenced by several parameters, which primarily include soil texture, soil structure and soil organic matter content. Organic matter may play an important role in soil structure, aggregation, infiltration and retention of water and other physical characteristics [64]. The overall abundance of pores, or "porosity", determines the maximum volume of water that the soil can contain. However, high porosity is not enough to maximize the services related to water retention capacity. The balanced arrangement of pores of different sizes, or "pore-size distribution", is a key property to retain water yet in a form available for plants, to deal with large quantities during wet periods and to ascertain air-filled pores during most of the time, to provide oxygen to the plant roots. The specific surface area of soil particles is another important soil property, as it relates to the surfaces that water can bind to, once in the soil. Many soils have a mixture of this particle (sand, silt and clay) types. Sandy soils generally have lower porosity and larger particles (and therefore larger pores), resulting in fairly rapid drainage and low water holding capacity [65-67]. Sandy soils need to be watered more frequently than finer-textured soils. Silty soils have a medium drainage rate and infiltration rate. Clayey soils drain slowly; have a low infiltration rate and higher field capacity as a result of smaller pores and larger porosity. Clays and silts have a similar available water-holding capacity. Good soil structure (clusters of soil particles) helps improve infiltration rate, drainage and available water holding capacity.

Pore size distribution influences the SWR capacity. Natural drainage in soils with a predominance of macropores is an asset in terms of maximizing infiltration and respiration of soils, by avoiding saturation and its consequences (oxygen depletion for plants and microorganisms, standing water or flooding events). Drainage into deeper layers of the soil also allows recharging the aquifers. On the other hand, fast and large drainage may be detrimental to water storage within the soil. Such soils tend to dry out quickly, which makes them prone to wind erosion and increases water stress for vegetation, with likely consequences in terms of irrigation requirements. On the other hand, soils should also be able to retain water for extended periods between rainfalls and this requires the presence of smaller pores. Soils with a predominance of small pores (meso and micropores), such as fine-textured soils, generally present a high capacity of water retention through prominent matrix forces, which hold water in the soil against the pull of gravity. The risk of soils with a predominance of micropores is poor drainage, which easily induces water saturation. This results both in poor aeration [68], which limits the soil suitability for agricultural purposes and often results in lower infiltration capacity, which makes them prone to runoff, increases flood risk as well as water erosion.

Soil water plays a very significant role in soil-plant growth relationships and highly influenced with cultivation of lands [69]. Water is held within the soil pores with varying degrees of forces depending upon the amount of water present. With the increasing amount of water in the soil, the forces of retention of water by the soil will be low and vice-versa. The movement and retention of water in the soil are primarily influenced by the characteristics of the soil [70] *viz.*, texture, nature of inorganic and organic colloids, type and amount of exchangeable cations, size and the total amount of pore spaces. Water held by soil with a high force of attraction is not available to the plants. The mineralogical composition of clays may further influence the capacity of soil to hold water, depending on their capacity to swell with water. Yet, this fraction has a limited interest as water storage for agricultural purposes as it still holds a large amount of water at the wilting point. Uniform plant root development and water movement in soil appear when soil profile bulk density is uniform; a condition that seldom exists in the field. Dense soils have low available water capacity because of decreased pore space. Sandy soils generally have bulk densities greater than clayey soils. Sandy soils have less total pore space than silty and clayey soils. Gravitational water flows through sandy soils much faster because the pores are much larger. Clayey soils hold more water than sandy soils because clayey soils have a larger volume of small, flat-shaped pore spaces that hold more capillary water. Clayey soil particles are flattened or plate-like in shape, thus, soil-water tension is also higher for a given volume of water. When percent of clay in the soil increases over about 40%, the available water content is reduced even though the total soil-water content may be greater. Permeability and drain ability of soil is directly related to the volume and size and shape of pore space.

CONCLUSIONS AND RECOMMENDATIONS

The particle size distribution of the soil sample taken from Holetta was analyzed using hydrometer techniques at Holetta Agricultural research center. The result indicated that the soil had the highest clay content followed by silt and sand. The soil of the study area is clayey soil which is determined using the textural triangle technique. Texture refers to the fineness or coarseness of the mineral particles in the soil and is determined by the relative amounts of different sized mineral particles (sand, silt, or clay) in the soil. The amount of sand, silt and clay present in the soil determine the soil texture. In coarse-textured soils, the sand is predominant and the soil is sandy soils. On the other hand, in medium-textured soils, the silt is predominant and the soil is loamy soils while in fine-textured soils, the clay is predominant and the soil is clayey soils. The texture of a soil is important because it determines soil characteristics that affect plant growth. A few of these characteristics are water-holding capacity, permeability and soil workability. Water-holding capacity is the ability of soil to retain water. Most plants require a steady supply of water and it is obtained from the soil. While plants need water, they also need air in the root zone. Sandy soils tend to be low in organic matter content and native fertility, low inability to retain moisture and nutrients, low in cation exchange and buffer capacities and rapidly permeable (i.e., they permit rapid movement of water and air).

Sandy soils usually have high bulk densities. They do require good water management (generally including more frequent irrigations, but little water is given per application and/or artificial drainage to fit the needs of a specific crop) and proper fertilization (meaning more frequent but lower quantities of nutrients per application). Total amounts of fertilizer per crop are usually quite high. Generally, soils with a larger percentage of sand are easier to work than soils with a larger percentage of clay. Finer-textured soils generally are more fertile, contain more organic matter, have higher cation exchange and buffer capacities, are better able to retain moisture and nutrients and permit less rapid movement of air and water. Clayey soil tends to be tighter, making it more difficult to break up or cultivate, whereas sandy soil is looser. It also takes longer for a clayey soil to dry after rain than sandy soil. Because of the better drainage, sandy soil can be worked sooner. In the case of wet clayey soil, the producer or gardener must wait longer for the soil to dry sufficiently. The laboratory result indicated that clay was the dominant soil particle (65.00%) followed by silt (18.75%) and sand (16.25%) in the study area. Generally, the soil of the study area is clayey soil which is very fertile but unproductive due to high water holding capacity, particularly in the peak rainy season. However, the productivity of this soil can be enhanced through draining excess water and applying compost and/or farmyard manure. Due to the high water holding capacity of this soil, irrigation water is applied less frequently but more water is given per application when compared with loamy and sandy soils.

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