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Tigray Regional State Bureau of Water Resource Development

Ruba Chemiet Pump Irrigation Project
Soil Resource Survey Final Report

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ACRONYM

Ava. P	Available Phosphorus
ESP	Exchangeable sodium percentage
CEC	Cation exchange capacity
cm	Centimeter
cmol	Centimole
ds	decisemin
FAO	Food and Agriculture Organization
Kg	Kilogram
M	Meter
m. a. s. l.	Meters Above Sea Level
Mg	Milligram
ml	Milliliter
mm	Millimeter

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1 CHAPTER I: INTRODUCTION

1.1 Background

A soil is an evolving entity maintained in the midst of a stream of geologic, biologic, and hydrologic activity. Individual soil bodies on the landscape and individual horizons within soil are the result of unequal distribution of materials within and between soils. Some soils and horizons within soils become enriched in certain substances; others become depleted. Water and energy flow through the soil surface, penetrate into the soil, and create an environment wherein primary minerals decompose and/or alter into secondary, mainly clay minerals (weathering). Plants and animals contribute to processes within the soil. Processes of soil formation are components of ecological studies of potential global climatic and other environmental disturbances (Vitousek 1994).

The soil classification based on external environmental factors and an assumed genesis as differentiating characteristics led to dissatisfaction among U.S. soil scientists in the 1950's and 1960's. It was stressed that there is a lot of uncertainty involved dealing with soil forming factors and changing environmental conditions in a landscape. Many processes go on in any soil, often offsetting one another. Hence, it is often difficult to identify the processes in soils because most soils are polygenetic. Furthermore, it is difficult to assess the relative importance of each soil forming factor contributing to the development of a distinct soil class. There was much concern of not being able to classify certain soils with adequate agreement because of uncertainties or disagreement concerning their genesis. The knowledge about processes was and still is limited, because we do not completely understand soil processes.

As a consequence a completely new system of soil classification was developed: The U.S. Soil Taxonomy (Soil Survey Staff, 1975). It is termed a 'natural' soil classification system, which attempts to organize the division of soils from a more holistic appraisal of soil attributes. The pedon is used as the sampling unit for soil classification and mapping in schemes employing the U.S. Soil Taxonomy. Diagnostic horizons are used to define different soil taxonomy. Since that time, the Keys to Soil Taxonomy have undergone six published revisions (Soil Survey Staff, 1994).

1.2 General objective

The overall objective of the soil survey is to provide soil description of the study area in order to prepare irrigation command area at Semi Detail level.

1.2.1 Specific objectives

- Investigating, evaluating and characterizing the distribution of different soils and landscapes at 1; 1,000 scale.
- Mapping of each land form and/or soil unit for sustainable development ;(soil mapping units will be structured.
- Surveying carry out with an overall density of 1 observation per 12 ha, through pit excavation and Augering 1 observation per 1000 meters but this depends on the nature of the soil (in places where more observations will be carried out to clearly define the features and extent of the soil).
- Soil survey approaches will be applied using three types such as pedogeological approach, free survey and, Grid survey techniques are used and all the soil physical and chemical properties will be investigated and interpreted
- Conduct detailed field level soil investigation by auguring, pit excavation and in-situ physical tests.
- Soil samples will be collected from profile pits , upon the decision of the soil surveyor for laboratory analysis. Samples from significant natural horizons will be taken to a depth of 2m unless impervious strata are encountered.

1.3 Scope of the work

The soil survey was carried out using FAO 2006 standard methods and procedures. to undertake different field investigational and in situ and laboratory tests; in order to meet the overall objectives of the study. Therefore, the scope of the study planned to attain:-

- Conduct detailed field level soil investigation by Augering, Pit excavation and in-situ physical test.
- Conduct standard soil physical and chemical analysis at laboratory level on soil samples that are collected at field.
- Conduct of infiltration test using double ring infiltrometer.
- Carry out auger observation as the rooting depth of most crops and profile pit at a depth of 2m, except obstructed by lithic contact at shallower depth.
- Conduct standard analyses of physical and chemical properties of the soil.

2 CHAPTER II: LITERATURE REVIEW

2.1 Importance and principles of soil taxonomy

Soil processes are not refused in the Soil Taxonomy but the focus is on soil properties rather than on processes. The rationale behind this is that processes are important to produce soil properties and that those are used for classification, i.e. genesis 'lies behind' the soil taxonomy. Soil processes provide a framework for understanding the Soil Taxonomy, for example, the soil forming process of decomposition and humification forms an A horizons. The soil properties recognizable in the field are a dark color of the A horizon with a granular soil structure. The soil properties selected should be observable or measurable, though instruments may be required for observation or measurement. Properties that can be measured quantitatively are to be preferred to those that can be determined only qualitatively.

The principles of Soil Taxonomy are:

- Classify soils on basis of properties
- Soil properties should be readily observable and / or measurable
- Soil properties should either affect soil genesis or result from soil genesis

2.2 Soil morphology and profile description

Soil morphology deals with the form and arrangement of soil features. Micro morphology is using micro morphological techniques (e.g. thin sections) and measurements in the laboratory. Field morphology is the study of soil morphological features in the field by thorough observation, description and interpretation.

Observations may be refined with the aid of a hand lens. Simple tests are also used in the field to record salient chemical properties (e.g., pH, presence of carbonates). In addition, field observations and measurements may be refined through a range of laboratory analytical procedures that include more sophisticated evaluation of chemical, biological and physical attributes. However, the quality of field description and sampling ultimately defines the utility of any subsequent laboratory analyses. A keen eye that can discern specific features and their relationship to adjoining features coupled with well-calibrated fingers that can distinguish among relative differences in physical properties of soil material are essential and can only be acquired and maintained through practice.

Field morphology starts with an in situ examination of a soil profile. Field descriptions are organized by subdividing a vertical exposure of the soil (soil profile) into reasonably distinct layers or horizons that differ appreciably from the horizons immediately above and below in one or more of the soil features listed below. The delineation of horizons is necessarily a somewhat subjective process because changes in soil attributes are often gradational rather than abrupt. Thus, obvious boundaries between horizons are not always apparent and their assignment may require integrated assessment of changes in several attributes before a sensible and defensible delineation can be made. Knowledge of similar soils and a well-defined rationale for the purpose of the description helps considerably in development of systematic criteria for defining and delineating horizons.

The following information is collected for assembling standard profile descriptions:

- Depth intervals of horizons or layers (measured from the top of the mineral horizon)
- Horizon boundary characteristics
- Color
- Texture
- Structure, pores
- Consistence
- Roots
- pH, effervescence
- Special features such as coatings, nodules, and concretions

Differences between horizons generally reflect the type and intensity of processes that have caused changes in the soil. Ideally, we should always be striving in our descriptions to maintain a link between process and morphology. In many soils, these differences are expressed by horizonation that lies approximately parallel to the land surface, which in turn reflects vertical partitioning in the type and intensity of the various processes that influence soil development. However, there are many exceptions to this preferred horizontal organization.

2.3 The Role of Soil Genesis and Classification

It is useful, important, and interesting to consider how the study of soil genesis and classification interacts with other fields of soil science and other scientific disciplines. This is especially true for technical soil classifications derived from scientifically based natural classifications systems like Soil Taxonomy (Buol and Denton 1984). Soil properties are primary reagents in field experimentation. Documentation of soil properties at research sites is essential for the successful transfer of research results to other locations.

Soil genesis and classification studies have made contributions to research design and data acquisition in other fields of soil science, including biogeochemical redistribution of nutrients in ecological systems, ecology of soil microbes and mycorrhizae, and the availability and distribution of plant essential nutrients such as phosphorus and nitrogen in different types of soils (Runge and McCracken 1984). Soil maps furnish basic inputs to soil conservation planning in the United States and provide information used in equations for predicting soil loss and water pollution potential under various management practices on different soils.

Characterization of soil properties is fundamental to all soil studies. Complete soil characterization for classification purposes requires that all horizons of the soil be analyzed. Many laboratory and greenhouse studies require only characterization of soil material from a few horizons, but practical application of the results obtained from such studies requires verification with field studies. Soil characterization methods draws heavily on methods of soil chemistry, physics, mineralogy, microbiology, and biochemistry. Conversely, methods and results initially obtained in soil characterization and soil genesis studies have been useful in perfecting methods of soil analysis by providing materials representative of all kinds of soil for analysis.

Soil genesis embraces the concept of soil as "a natural entity to be studied as a thing complete in itself" (Cline 1961). This concept has survived the fragmentation of soil science into the sub disciplines of soil chemistry, soil physics, soil microbiology, soil fertility, and soil management by drawing upon and integrating the concepts, theories, and facts of these subfields of soil science into a holistic, integrated, multidisciplinary view of soil as a natural entity. Soil genesis and classification, or pedology, may also be likened to a system of bridges connecting the disciplinary islands of geology, biology, chemistry, physics, geography, climatology, agricultural sciences, economics, anthropology, and archeology. The interdisciplinary nature of this field of soil science gives it added importance in the training of scientists (Abelson 1964).

Soil genesis and classification and its allied activities therefore have many interactions with and contributions to fields of science other than the science of soils. Soil genesis and soil classification have some roots in geology, for they grew out of the study and mapping of rocks. The close ties between geology and soil science stem from the fact that most soils are derived from geologic materials such as granite, limestone, glacial drift, loess, and alluvium. Several of the early pioneer soil scientists were geologists by training. Because differences among soils are due in part to the different landforms they occupy, and because age of the soil is related to the stability of the surface on which they have formed, close ties between soil specialists in genesis and classification and geologists specializing in geomorphology continue to be strong and mutually beneficial.

Soil genesis and classification is seldom concerned with entire geological deposits, but rather deal with the upper portion of the deposit that has been influenced by plant and animal activity and by the intrusion of water and energy from the land surface. Therefore, soil genesis and classification, which deals with the dynamic, biologically active soil system, must also be concerned with biology, especially the sub sciences of ecology, microbiology, plant physiology, and botany. Hans Jenny (1980) regarded soil and vegetation as coupled systems and thus an ecosystem. A knowledge and awareness of plant-soil interactions, meteorology, and hydrology are essential for soil scientists interested in soil genesis and classification.

Soil underpins human food production and is a very significant component in our total stock of natural resources. Production economists call on soil scientists for data and estimates of the productivity of various soils under defined systems of management. Natural resource economists are concerned about the amount and distribution of useful productive land. Planners at local, state, regional, and national levels use soil surveys and soil interpretations for land-use planning, environmental protection, and selection of building and highway sites, tax assessment, and land evaluation (Simonson 1974; Bauer 1973; Jarvis and Mackney 1979). This places additional responsibility on soil classifiers and interpretation specialists to provide sound, scientifically based evaluations of flooding, structural instability, and other economic potentials of individual kinds of soil. Soil scientists must consider economic and resource conservation factors in the preparation of technical and natural classification systems. Archeologists and anthropologists utilize soil information and data to date construction and destruction of human settlements and explain changes in agricultural practices (Olson 1981; Harrison and Turner 1978).

Source: Soil Genesis and Classification, Sixth Edition. S. W. Buol, R. J. Southard, R. C. Graham and P. A. McDaniel. © 2011 John Wiley & Sons, Inc. Published 2011 by John Wiley & Sons, Inc.

2.4 Importance of Irrigation on Improving the Agricultural Productivity

Water plays a major role in human development (without water no life) and hence any behavior that provides an effective use of water or improves the quality of existing water sources contributes to human survival. Access to water, poverty and people's livelihoods are interlinked. At the same time, water is becoming a scarce resource in many countries, particularly in SSA (UN, 2005). Hence in arid and semiarid regions of the world such as Ethiopia, mostly faces with inadequate, irregular and erratic nature of rainfall. In addition with recurrent drought lack of efficient use of scarcely available water amplified the impact of water scarcity in agricultural production and productivity. The reduction of agricultural production results from a combination of many factors, such as crop management, crop genetics and biotic stress. Achieving more agricultural production to meet the growing demand for food, feed and fuel and fiber for the rapidly increasing population is a continuing and ever increasing challenge.

Water, soil, air and sunshine are the four main determinants for plant growth. Therefore, water is essential to plant-growth and crop-production (Widtose, 2001). Therefore, Water is important for agriculture, household consumption, industry, hydropower, navigation, fisheries, recreation, and ecosystems. Without water there is no food production. When there is adequate supply of water, crops grow best and produce most.

Water is a basic need for human beings, plants and animals. It is essential for their metabolic processes. Therefore, water is vital for all agriculture types. According to Dupriez and De Leener (2002), the sources of water for crop production are rainfall and irrigation water. The two types of agriculture seen from the perspective of water management are:

Rain fed cultivation is agricultural production of crop depending entirely on the rain. It relies on the rainfall timing and distribution. Rain fed farming is characterized by plateau cultivation and dry land cropping. Rain fed farming is mostly practiced during one growing season, uni modal, but in some areas two growing seasons (bimodal production) are possible.

Irrigated cultivation is agricultural production using irrigation water in addition to rainfall. Irrigated crops benefit from man-made watering with the help of water pipes, canals, reservoirs and pumps. The source of irrigation water is surface water or groundwater. Surface water is obtained in ponds, lakes, rivers and seas whereas groundwater is obtained underground in liquid or vapor state (Dupriez and De Leener, 2002).

Irrigation has served as one key driver behind growth in agricultural productivity, increasing household income and alleviation of rural poverty, which highlights the various ways that irrigation could have an impact on poverty. According to Haile (2008), there are four interrelated mechanisms by which irrigated agriculture can reduce poverty, through: (i) increasing production and income, and reduction of food prices, that helps very poor households meet the basic needs and associated with improvements in household overall economic welfare, (ii) protecting against risks of crop loss due to erratic, unreliable or insufficient rainwater supplies, (iii) promoting greater use of yield enhancing farm inputs and (iv) creation of additional employment, which together enables people to move out of the poverty cycle. In the same way, (Zhou et al., 2008) mentioned that irrigation contributes to agricultural production in two ways: increasing crop yields, and enabling farmers to increase cropping intensity and switch to high-value crops. Therefore, irrigation can be an indispensable technological intervention to increase household income. This study will examine the impacts of irrigation on incomes at the household level for one region of Ethiopia.

2.5 Irrigation Developments, Challenges and Practices in Tigray

Tigray's agriculture is based on ox-plough cultivation of predominantly cereal crops. This technology has prevailed without modification for thousands of years, harvesting the same land over and over again. The level of subsistence, except for periods of good rains, has declined radically during the past decades, with almost everything produced being consumed at the farm household level.

Quite apart from the erratic nature of rain water on which Tigray's agricultural production depends almost entirely, Tigray's agrarian system has, within it superimposed, a fast accelerating population growth, resulting in high density per arable land, causing, over time, the steady decline in soil and labor productivities. With such deterioration has come about the deterioration of the terms of trade of agriculture affecting all areas of economic management. The Tigray's characteristics is general for all countries in the Horn of Africa and appropriately reflect the prevailing situation in the Sahel as well as in other African countries suffering from drought desertification land and environmental degradation, sometimes compounded by armed ethnic, tribal and civil conflicts (CoSAERT, 1994).

It is in consideration of these potentials, that the Transitional Government of Ethiopia requested the Economic Commission for Africa (UNECA) and the Food and Agriculture Organization of the United Nations (FAO) to design a participatory rural development program based on a comprehensive water-harvesting and soil conservation scheme, embodying watershed management measures and the provision of well designed micro-dam integrated systems for the storage and ultimate utilization of the seasonal surface runoff water for irrigation and for human and livestock use (CoSAERT, 1994).

The development packages proposed for study and integration into an Action Plan include the consideration of a well thought out institution building process that would enable Tigray to evolve real and self-reliant development. The supplementary package proposed also include the construction of 500 micro-dams supported by appropriate irrigation infrastructures; a modern soil laboratory; appropriate labor power enhancing technologies, functioning at all levels of development; an efficient development support extension communication system; the evolvement of a capacity to terrace 200,000 hectares of land every year and the provision of several million seedlings of forestry and agronomy, supported by 81 newly established seedling nurseries (CoSAERT, 1994).

3 CHAPTER III: MATERIALS AND METHODS

3.1 Study Site Description

3.1.1 Location of the study area

Chemiet pump irrigation project is located in Tigray regionional state, central zone, werileke Woreda. Geographical location of the site Easting-526737and Northing-1548921 UTM at elevation of 1717.5 m.a.s.l.

The study sites were designated by ten profile pits codes namely ADHTP01, 02.. and 10.

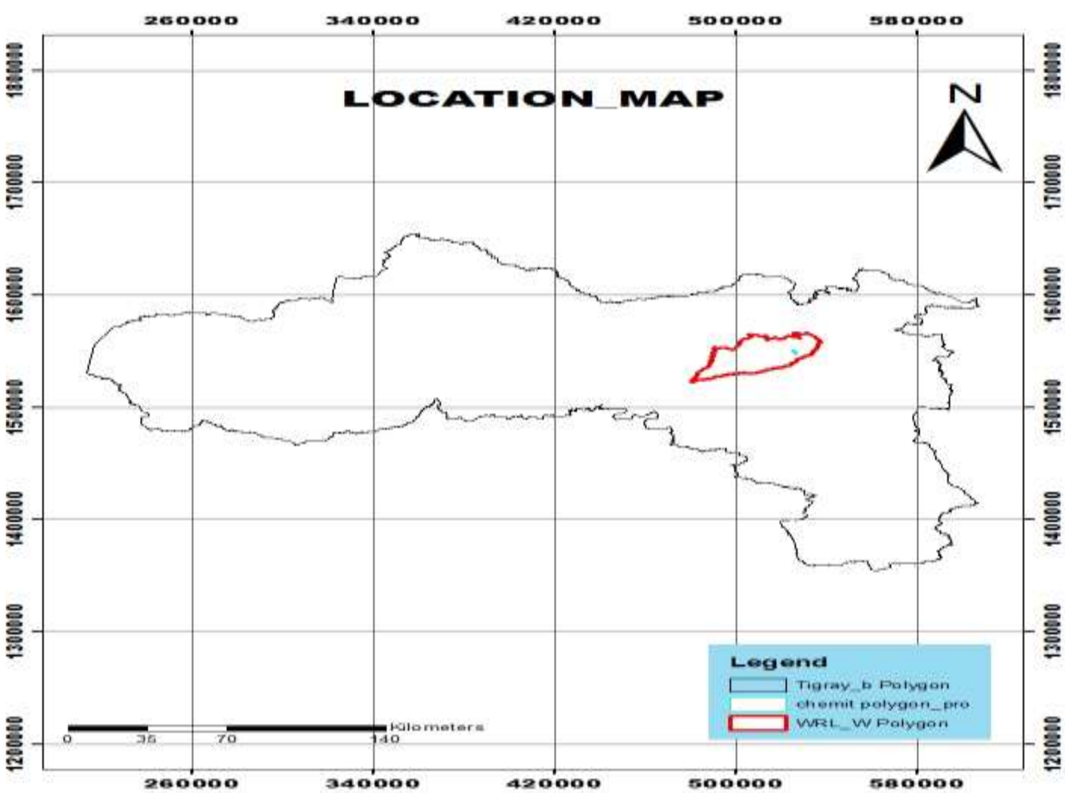

Figure 1: Location map

3.1.2 Land use and Vegetation

The land use of the study area is cultivated land, woodland land, forest land, shrub land and miscellaneous land. The dominant land use type is cultivated land. Enclosures, which are protected areas enriched by artificial and with natural remnant vegetation are also common where there is very shallow soil depth or abundant massive rock cover with many factures, steep to very steep slopes, mainly well conserved by physical structures.

Big trees together with bushes and shrubs are found in cultivated, closures and plantation areas.

3.1.3 Geology of the Project Area

GEOLOGICAL SETTING

The regional geological map of the project area comprises Precambrian metamorphic rocks, Upper Palaeozoic to Mesozoic, Cenozoic volcanic rocks and recent deposits. Based on the Geological Map of Ethiopia (GSE) and Geological Map of Adigrat area (Adigrat Sheet) the project area comprises; Tsedya slate, Werie slate, Assem limestone, Edaga Arbi Glacials, Enticho sandstone and Tsaliet group. The dominant rock unit in the immediate project boundary is Precambrian Upper Complex unit (metamorphosed sedimentary rocks).

Principal Rock Types

There are two general classes of rock in the project: Igneous and Metamorphic rocks. Igneous rocks were exposed along streambeds of Chemiet River, which is fresh, fine-grained, green to black color, generally hard to extremely hard rock, typically basalt rock.

The metamorphic rocks formed from existing rocks that have been subjected to heat and pressure are slate (metamorphosed shale) and slat with limestone intercalation, and slate limestone with thin marble intercalation. Slate was the dominant rock in the ground. Which was outcropped as laminated, layered and bedded all appears in a variety of colors and is highly variable in hardness. Slate and thinly layered limestones are common in the gentle slopes and ridge maker terrains, in this areas was termed as interbedded.

The dominant geologic formation along the pump, pipeline and canals is black, grey and brown slate rock, sometimes near elevated terrain interbedded with black, fresh and crystalline limestone.

3.1.4 Topography

The topographic features of the study area vary from flatter to steeper slopes due to the presence of depressions and ridges.

3.1.5 Slope classification of the study area

The entire study area was categorized into 5 slopes based on FAO classification, two geological features (Igneous rock and alluvial) and two land cover classes (Cultivable land and Forest). The slope of the area was derived from a 30 m by 30 m resolution DEM Aster image obtained from Ethiopian Mapping Agency (EMA) and classified based on the FAO soil description guideline (FAO, 2007) as shown in Table below.

Table 1: **Slope classification of the command area**

Slope	Area_ha	Percent (%)
0-2	44	45.8
2-5	31	31.3
5-8	16	16.7
8-15	4	4.1
15-30	2	2.1
Total	97	100

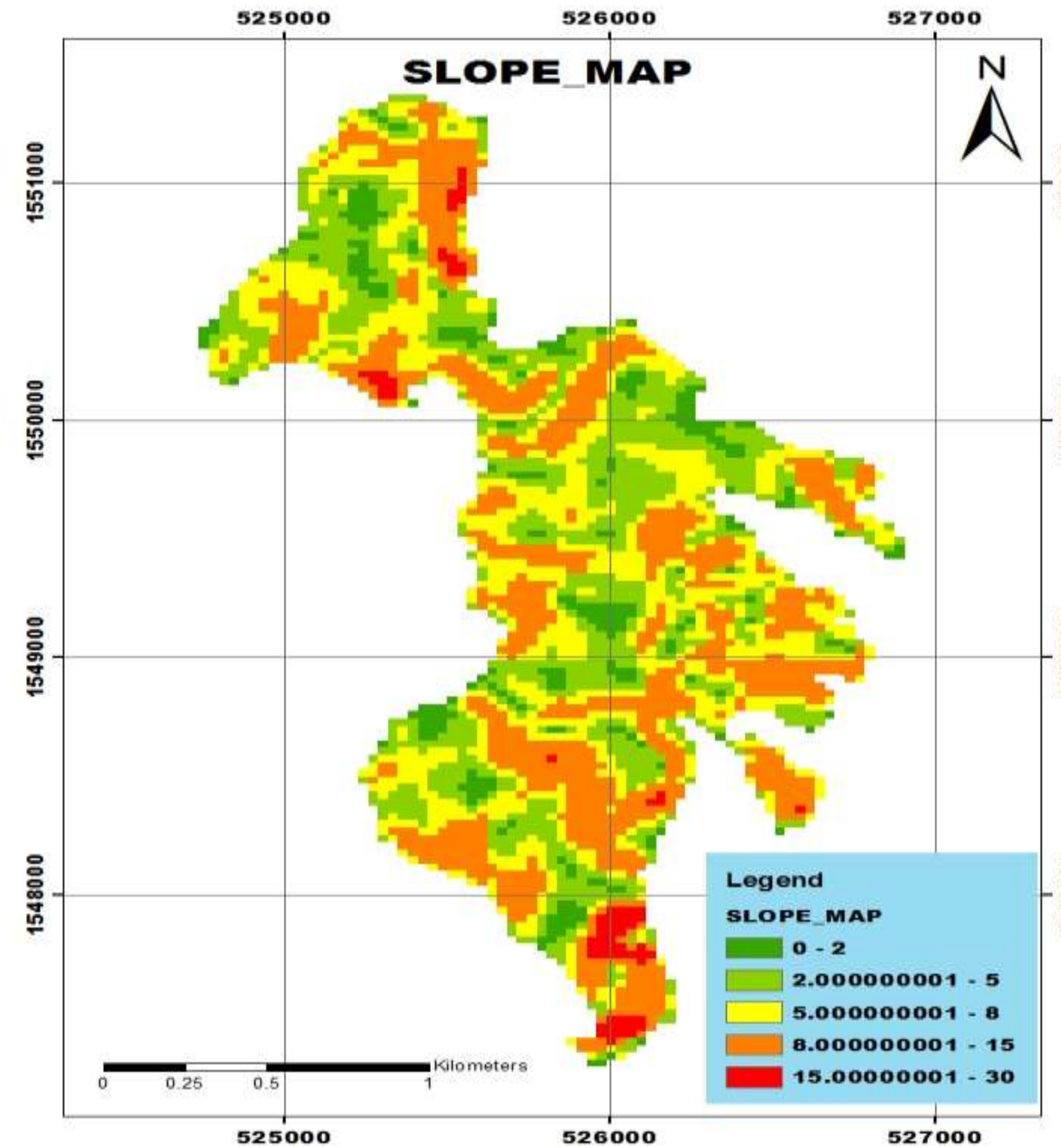

Figure 2**: Slope map of the command area**

3.1.6 Soil

The dominant soils types are cambisols, Regosols, and Leptosols. These soils are not uniformly distributed in the command area. The sandy loam soils are dominant almost in all part of the command area.

3.2 METHODE

3.2.1 Sampling technique and preparation

This study was carried out In order to evaluate the different land use types with their soil genesis classification and their Physico- chemical properties at field and laboratory experiments.

The methods of sample selection were Geopedologic Approach and we had Ten profile pits at different areas and land use types.

During the field experiment soil profile description sheet was prepared by the surveyor for describing all the physical features of the profile such as the soil color, consistency, field textural class, distinctness, topography, Mottling…etc were observed and analyzed in the field.

3.2.2 Soil sampling design at office level

Considering the aforementioned constraints and the proposed model of the soil mapping Activity, a soil sampling scheme was designed that would consider representative sites that would reveal the spectrum of soil spatial variability.

Using the produced landscape map, variability of different landscapes and relief types were analyzed as well as their relation to soil formation, thereby assess in spatial Variability and composition of the terrain component.

3.3 Soil Sample collection and Physico-chemical Analysis

3.3.1 Soil Sample Collection at field level

In order to interpret soil characteristics, soil physical properties were described in the field and soil samples of 1kg were collected from each horizon in order to determine Physico chemical properties. For the determination of textural class, permanent wilting point, field capacity, Bulk density, moisture content organic carbon (C), nitrogen (N), phosphorus (P), texture, exchangeable bases and Cation Exchange Capacity (CEC), only the upper 50 cm of soil were considered since it is the useful root depth for most agricultural crops, and so it is useful for the evaluation of agricultural land.

To obtain the texture the Gravimetric Method (pipette) and United States Department of Agriculture (USDA) Soil Textural Classification System was followed. In order to interpret laboratory analytical results.

Considering the site characteristics and the profile description, a preliminary soil classification was made in field. The samples taken from each horizon of each described profile were an important input for determining the physicochemical properties of soil and soil classification. Soil profiles were reclassified considering all soil properties observed in the field and in the laboratory. Soils were classified at the reference group, and at prefix–suffix qualifiers levels.

The major physical properties of the soil used as a base for classification were texture, depth, color, drainage characteristics, and profile development. The most important chemical characteristics of the soils used as a base for classification were cation exchangeable capacity, base saturation, organic carbon, exchangeable sodium percentage, free carbonates, pH, and electrical conductivity. ten soil profiles were dug among them only four are sampled and described during the survey, 50 Augering was performed in areas where there was the need to define boundaries between different soil classes. Sites with rocky or stony soils were not described in detail, but a preliminary Classification was still made.

3.3.2 Soil Physico-Chemical Analysis

Laboratory Analysis

In the laboratory, soil samples were analyzed for texture using (Hydrometer method) according to Gee and Bauder, 1986), pH (suspension of a 1: 1.2 soil to water ratio (Sahlemedin and Taye, 2000), total N (Kjedahl method (Jackson,1958), available P (Olsen method (Olsen, et al,1954), available K (Morgan method(Morgan, 1941), exchangeable Ca, Mg, K & Na (Ammonium Acetate method (Okalebo, et al, 1993), CEC ((Ammonium Acetate method (Okalebo, et al, 1993)), ECe (EC Meter (Sahlemedin and Taye, 2000), Organic Carbon using Walkley and Black method (Walkley and Black, 1934).

4 CHAPTER IV: RESULTS AND DISCUSSION

4.1 Soil profiles

Ten soil profiles were described in the course of this soil survey. four out of the ten profiles were completely described, and Eighteen soil samples being sent to Addis Ababa water works design and supervision soil laboratory center for chemical and physical analyses. Sites with rocky or stony soils were not described in detail, but a preliminary Classification was still made.

50 Augering was performed in areas where there was the need to define boundaries between different soil classes. All profiles and site descriptions were classified based on WRB 2006 and recorded in a soil Profile sheet.

4.1.1 Infiltration rates

The measured infiltration rate of the command area is suitable (0.32cm/h) which is optimum as compared with the expected range for soil (Landon,et al,1991).Therefore, generally the result of the infiltration rate measurement is not dependable to draw conclusive recommendation; however, it gives indication regarding the infiltration rate of the soils. Accordingly, the average of mean Therefore, literature values should be used for different purposes of the study.

4.2 Major soils of the study area

Based on the assessment made, the dominant soil types were found to be, 1- mineral soils conditioned by topography, 2- mineral soils conditioned by limited age.

Mineral soils conditioned by topography include Regosols with eurtic qualifiers (alluvial soils) Leptosol with Lithic qualifier. The mineral soils conditioned by limited age are Cambisols with eurtic qualifiers. The area distribution of the major soil types are Cambisols 50.5 %, Leptosols 23 % , Regosols 26.5 % .The proportion of area occupied by the corresponding major soil types is shown in map and Table below.

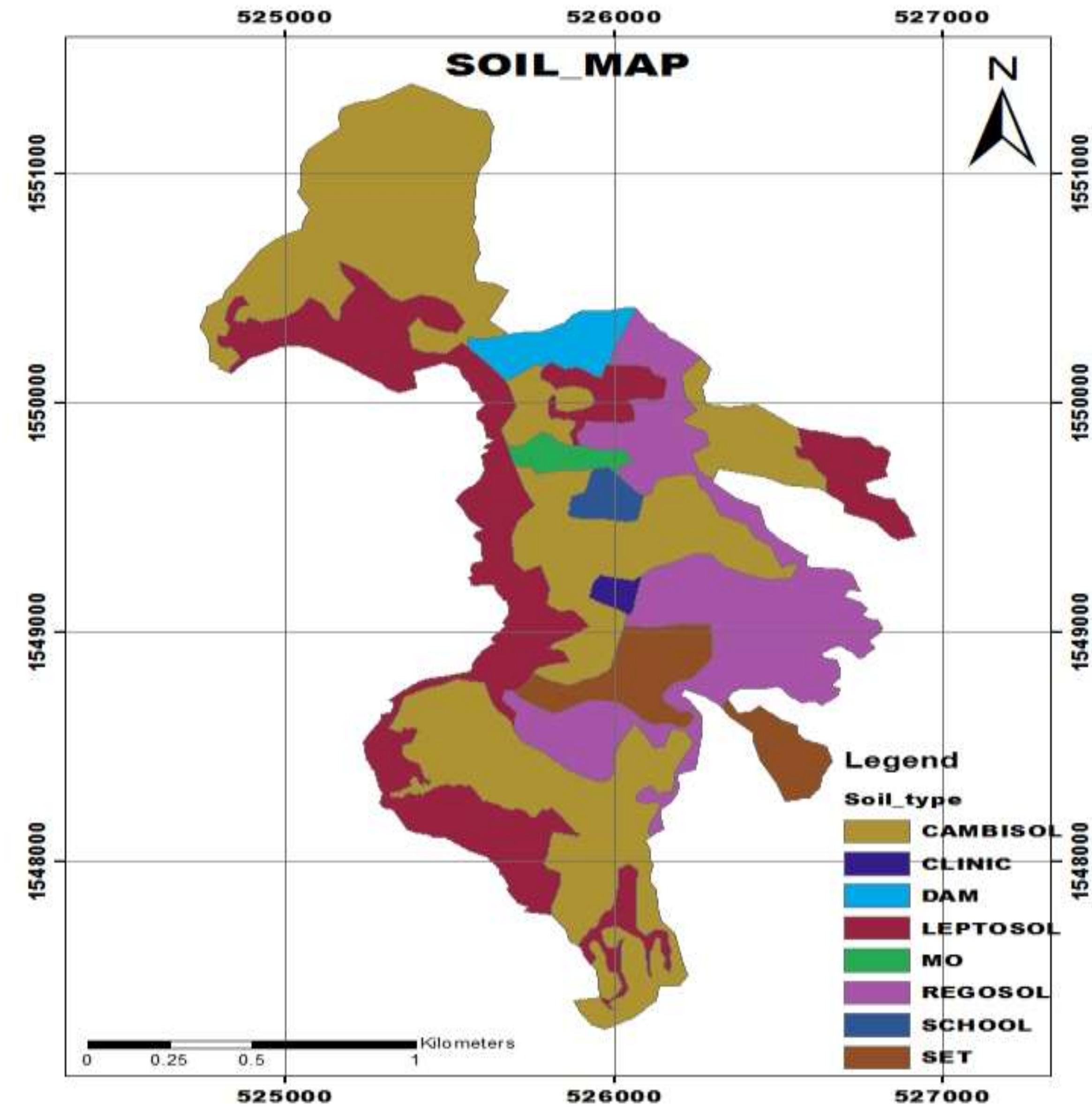

Figure 3: **Major soils of the study area**

Table 2: **Soil type and its coverage**

Soil type	Area coverage (ha)	Percentage (%)
Cambisol	49.5	51.6
Regosol	22.5	23.4
Leptosol	24	25
Total	96	100

4.3 Cambisols

Cambisols are the dominant soils in the study area, occurring mainly in the northern part of the study area. These are soils with an initial stage of subsurface soil horizon differentiation. They occur in slopes, denudation surfaces and in some alluvial deposits in the study area. The parent material is derived from a wide variety of rocks, the most common of which is fossiliferous limestone. The profiles are characterized by slight transformation of the parent material and evidence changes in soil structure, color and clay content, but there is an absence of appreciable quantities of illuviated clay or carbonate content, organic matter, Al and/or Fe compounds. The topography varies from flat to gently sloping surfaces of alluvial deposits.

Bulk density is high when the soils are dry and low when wet. Water infiltration is moderately high.

The Cambisols in the study area have a relatively low water storage capacity in the root zone of the upper 1m of the soil profile, due to their depth and sand content. The soil moisture content in the deeper layers is higher, apparently due to compression effects on metric potential. As this study area is characterized by uncertain rainfall, the water stored in the soil profile is very important for survival of crops during the growing season until the end of the rainy season.

4.4 Leptosols

4.4.1 Physical and chemical property of Leptosols

4.4.1.1 Physical property

Leptosols of the study area, occurring mainly in the hill part of the study area mainly on the Mountains and dikes but are also present in the Plateau and dissected plateaus. Their landscapes include isolated mountain blocks or successions of mountains of differing elevations. The mountain surfaces are made up of stony and rocky formations without soil development.

They are very shallow soils over continuous rock, and soils that are extremely gravelly or stony. These characteristics make these soils of limited suitability for agriculture.

Due to the limited amount of soil material in Leptosols, soil profiles were difficult to dig and no soil samples were taken.

4.5 Regosols

4.5.1 Physical and chemical property of Regosol

4.5.1.1 Physical property

Regosols comprise all the soils that cannot be referred to any of other Reference Soil Groups. These soils are characteristic of arid and semi-arid environments, and due to their aridity the soil profiles do not show diagnostic horizons that may be referred to any of the previous RSG. These soils occur in variable relief types in the landscape, particularly on plantation surfaces, slopes, denudation surfaces, mesas and pediments of dissected plateaus; the topography is generally undulating to hilly. The parent material consists of unconsolidated fine-grained material originating from different rock types, including basement complexes, limestone and sandstone.

Soil color was measured at both dry and moist status. The color of the soil profiles within the depth of 0-100cm when dry. Accordingly, it was brown throughout this depth.

The dry consistence of the soil was soft and the moist consistence of the soil of the Profile was friable for all horizons in the study area. The wet consistence of the soil study area was neither sticky nor plastic. The structure of the soil was friable.

A limited number of soil profile samples were examined for physical and chemical analysis as most of these soils in the study are shallow. The data of the tested soil profiles indicate a uniform sandy loam texture and moderately high bulk density.

4.5.1.2 Chemical property

Depending on soil chemical properties, the observed values of PH in the soil horizon ranges from 6.59 to 8 with the mean value of 7.07 according to the rating set by Tekalign (1991) rated as neutral. EC in the soil horizons ranged from 0.023 to 0.56 with the mean value of 0.099 dS m-1 in the Profile. In addition, the values of EC measured for the profile were increased with depth. Generally, the EC values measured throughout the depths of the soils in the profile indicated the concentration of soluble salts were none saline at which growth and productivity of most agricultural crops are not affected.

Exchangeable Ca was found to predominate the exchange complex of the soil colloidal particles in the entire horizon of the profiles. The highest exchangeable Ca (12.2Meq/L) among the horizons was obtained in the bottom layer of the profile followed by decreasing upward the depth to 4.2Meq/L in the profile. Generally, the concentrations of exchangeable Ca increased consistently with increasing depth. According to the rating set by Booker tropical soil manual(1991) all of the soils in the profile may be rated as medium in their exchangeable Ca contents. Exchangeable Mg was also highest 5.6 ppm in the Profile followed by 2.2 ppm in the horizon of the profiles. According to the rating set by FAO (2006), the soils in the study area is rated as high in their exchangeable Mg contents.

The contents of exchangeable K and Na in the profile varied from 31.6 ppm to 63.2 ppm and 20 ppm to 30.8 respectively. Thus, according to the criteria set by FAO (2006) the soils of all horizons of the profile rated as medium in K and low in Na content.

The values of soil organic carbon in the profile varied from 0.807% to 1.985% of the soil Profile. The organic carbon percentage decreases with depth with maximum value at the top layer 1.985 %. These highest amounts of soil organic matter in the upper horizons could be the frequent addition and accumulation at different times. According to Tekalign (1991), the OC contents of the soil profile could be rated as low.

Total nitrogen of the profile ranged from 0.043% to 0.099% of the soil profile. According to Tekaligh (1991), total N contents of the soil profile could be rated as low.

Within a profile the Olsen extractable soil P values were the highest in the surface horizon of the profile 7.601ppm and the lowest 5.671. Based on the rating set by Landon (1991), the available phosphorus in the soil profile is moderate.

Cation exchange capacity (CEC) of the soils of the study area across the surface and subsurface horizons ranged from 11.97 Meq/100gm of soil to 26.56 Meq/100gm soil. CEC of the soils consistently decreased with soil depth.

According to the rating suggested by Hazelton and Murphy (2007), the CEC of the soils of the study area ranged from low to high.

5 CHAPTER V: CONCLUSION AND RECOMMENDATION

5.1 CONCULUSION

In an arid and semi-arid climate it is recognized that the major chemical factors limiting crop production are usually related to the increase of soluble salts in the soil. Therefore attention is always focused on chemical analyses to assess the types and amount of soluble salts and amount of exchangeable sodium associated with the soil clay.

- ❖ The levels of exchangeable sodium are generally low. These characteristics are Favorable for crop production.
- ❖ The color of the surface soils of the present study varied from brown to dark brown (moist and dry). The soil structure varied from weak fine to medium granular in the surface horizon to strong medium to coarse angular blocky at the different depth of the soil profiles.
- ❖ The soil consistence also varied from soft (dry), very friable (moist), slightly sticky and none plastic (wet) to extremely hard (dry), friable (moist), extremely sticky and plastic (wet) in the soils of the present study area. The surface soil horizons had the textural variation across the sites of each profile area.
- ❖ In general, soils are rated as neutral in their PH. Electrical conductivity of the soils at the surface as well as the subsoil horizons was below unity and in general, it cannot affect the growth of most agricultural crops and the soils were salt free.
- ❖ Among exchangeable bases (Ca, Mg, K and Na), the exchange complex of the soils of the present study was predominantly occupied by divalent basic cations (exchangeable Ca followed by exchangeable Mg). By and large, the magnitudes of exchangeable Ca and Mg were rated as medium to high. The exchangeable K showed insignificant variation between profiles and horizons within the profiles as well. However, the rate of exchangeable K was rated as medium.
- ❖ Finally, according to the results taken from the laboratory, three major soil units (Cambisols Regosol and Leptosols) were identified and characterized based on the FAO/WRB (2006) classification legend.

5.2 RECOMMENDATION

- Management of soil for agricultural purposes requires a combination of agronomic and management practices depending on a careful definition of the main production constraints and requirements based on a detailed, comprehensive investigation of soil characteristics, water monitoring (rainfall, surface water and groundwater) are required.
- Soil organic matter is important for physical, chemical and biological soil properties. This can be improved by leaving and incorporating crop residues in the soil and by adding organic manures to the soil.
- Application of Ammonium Sulfate reduces the pH significantly. Therefore, Ammonium sulfate has the tendency to improve the pH of the soil

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APPENDIX_ 1 PHYSICAL PROPERTY OF SELECTED PROFILES

Table Soil Morphological Properties of profile code ADH01

Horizons			Ap	A	B	
Depth			0-22cm	22-100cm	>100cm	
Color	Dry		7.5YR4/4-Brown	7.5YR3/3- dark Brown	7.5YR2.5/2-very dark brown	
	Moist		7.5YR3/3-DARK Brown	7.5YR2.5/2-very DARK brown	7.5YR2.5/1-BLACK	
Distinctness			clear	Diffuse	Diffuse	
Topography			Abrupt	smooth	wavy	
Mottling	Abundance		None	None	None	
	Size		None	None	None	
	Contrast		None	None	None	
	Boundary		None	None	None	
	Color		None	None	None	
CaCo3			None	None	None	
Cutans			No	No	No	
Structure	size		Medium	Medium	coarse	
	Type		Sub angular blocky	Sub angular blocky	Sub angular blocky	
Consistence	Dry		slightly hard	Slightly hard	Hard	
	Moist		soft	Slightly hard	Hard	
	Wet	Sticky	Slightly sticky	Slightly sticky	Sticky	
		Plastic	none	Slightly plastic	Slightly Plastic	
Mineral nodules	Amount		None (0)	None		
	Kind		None	None		
	Size		None	None		
	Shape		None	None		
	Hardness		None	None		
	Nature		None	none		

Table - Soil Morphological Properties of profile code ADH02

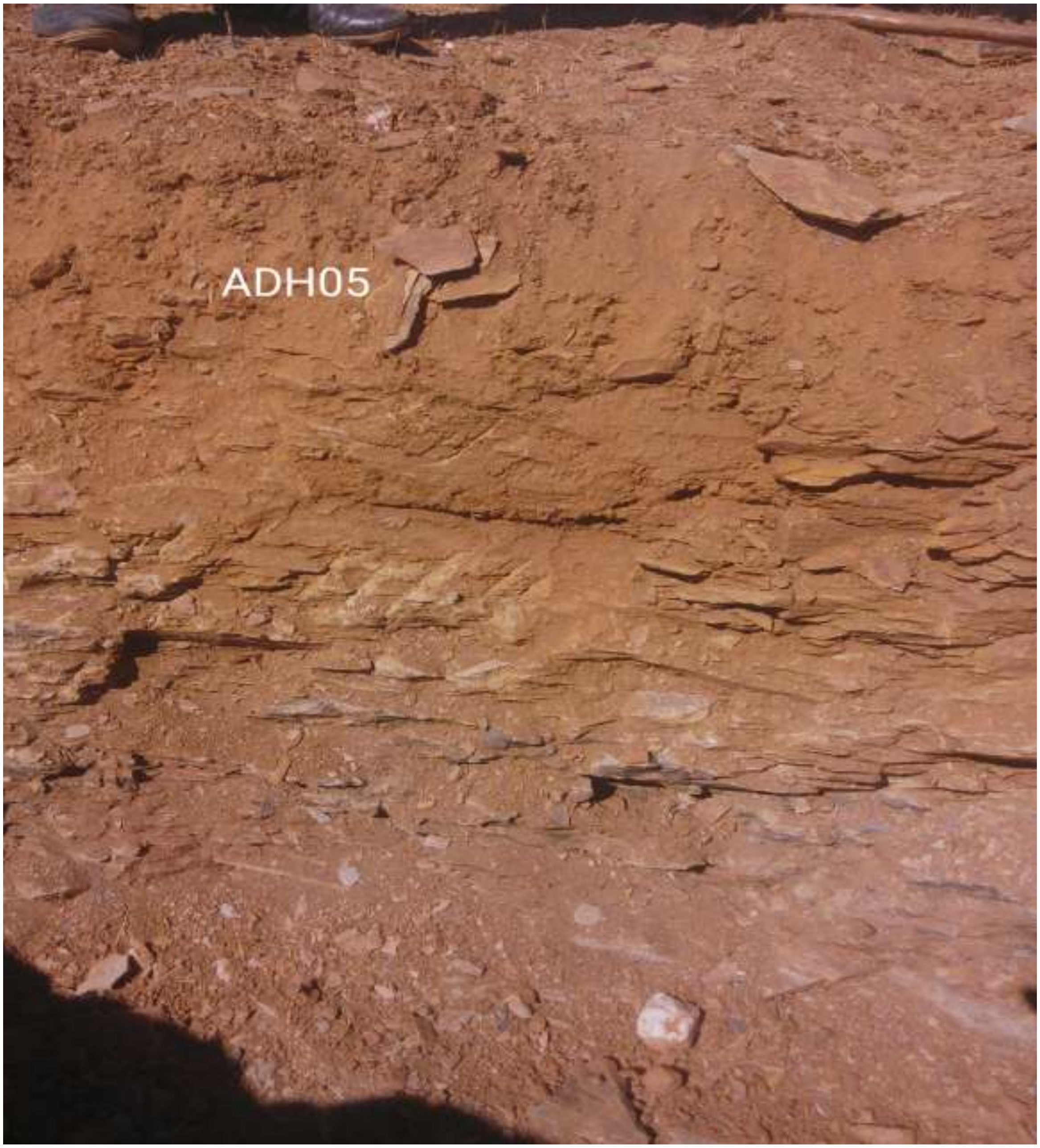
Horizons			Ap	AB	B	
Depth			0-10	10-90	>90	
Color	Dry		7.5YR4/4-BROWN	7.5YR4/3-BROWN	7.5YR3/2-dark brown	
	Moist		7.5YR4/3-BROWN	7.5YR3/3-DARK BROWN	7.5YR3/1-VERY DARK GRAY	
Distinctness			Abrupt	Wavy	Wavy	
Topography			Smooth	Smooth	Smooth	
Mottling	Abundance		None	None	None	
	Size		None	None	None	
	Contrast		None	------	None	
	Boundary		None	------	None	
	Color		None	------	None	
CaCo3			None	-------	None	
Cutans			No	------	None	
Structure	size		Medium	Coarse	Coarse	
	Type		Blocky sub angular	Blocky sub angular	Blocky	
Consistence	Dry		Soft	Hard	Hard	
	Moist		Friable	Slightly hard	Hard	
	Wet	Sticky	Slightly stick	Slightly stick	Slightly stick	
		Plastic	Slightly plastic	Slightly plastic	Slightly plastic	
Mineral nodules	Amount		No	-------	No	
	Kind		No	------	No	
	Size		No	-------	-----	
	Shape		No	------	-----	
	Hardness		No	------	----	
	Nature		No	---	----	

-

Table - Soil Morphological Properties of profile codeADHTP_10

Horizons			Ap	A	B	
Depth			0-30	30-60	> 60	
Color	Dry		7.5YR4/4-BROWN	7.5YR4/3- brown	7.5YR3/1-Very dark gray	
	Moist		7.5YR4/3- BROWN	7.5YR3/1-Very dark gray	7.5YR3/1-Very dark gray	
Distinctness			Abrupt	Abrupt	Abrupt	
Topography			Clear	Smooth	Smooth	
Mottling	Abundance		None	------	None	
	Size		None	--------	None	
	Contrast		None	--------	None	
	Boundary		None	-----------	None	
	Color		None	----------	None	
Caco3			None	-------	None	
Cutans			No	------	None	
Structure	Size		Fine gravel	Medium	Medium	
	Type		Granular	Blocky sub angular	Blocky sub angular	
Consistence	Dry		Soft	Slightly hard	Slightly hard	
	Moist		Friable	Soft	Soft	
	Wet	Sticky	None	Slightly stick	Slightly stick	
		Plastic	None	Slightly plastic	Slightly plastic	
Mineral nodules	Amount		------	None	None	
	Kind		------	None	None	
	Size		------	None	None	
	Shape		--------	None	None	
	Hardness		--------	None	None	
	Nature		--------	None	None	

APPENDIX_2 PHOTOS OF PROFILE PITS




ADH-04

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ENAO
Testing Laboratory T0021

TEST REPORT

Client Name; Tigray water works study Design & Supervision enterprise
Address; Mekelle
Attention: Atsbha G/anenya
Tel.: 0914004028
e-mail; --

Report No.: RMSL-0304/18
Samples Received: 12/01/2018
Analysis Completed: 10/02/2018
Date of Report: 12/02/2018
Status of Report: Final

Nominated Representative
G/Giorgis Aregai, *QA/QC Head*

Client Ref.: Your request for the lab. testing of samples
No. Samples: 14 0f 167
Sample Type: Soil

Technical Signatories:
Girmay Hailu, Lab.Case team Head

For Administrative Case only
Name: G/medhine Berhe Responsibility: Centre Director Signature: Date:

Condition of samples:
This report relates specifically to the sample(s) tested in so far as that the sample(s) is truly representative of the sample delivered to our laboratory. All pages of this report have been checked and approved for release.

No.	Sample ID	Anayzed Parameters							Texiture			
		PH	EC	MC	OC	CEC	AV.P	TN	% sand	% silt	% clay	class
45	MCTP03	7.320	0.029	2.145	1.164	13.687	7.252	0.055	36.0	34.0	30.0	Clay loam
46	ADH02	8.000	0.079	2.543	1.100	18.253	6.522	0.050	34.0	36.0	30.0	Clay loam
47	MCTP04	7.270	0.142	2.208	1.608	16.353	6.746	0.070	38.0	34.0	28.0	Clay loam
48	ADH06	6.990	0.049	1.958	1.114	13.458	6.301	0.055	32.0	36.0	32.0	Clay loam
49	ADH02	6.990	0.045	2.124	1.342	11.969	6.740	0.062	44.0	34.0	22.0	Loam
50	MCTP03	7.280	0.035	3.263	1.361	16.336	8.096	0.057	42.0	38.0	20.0	Loam
51	ADH04	6.920	0.027	4.690	1.249	14.028	7.601	0.056	30.0	40.0	30.0	Clay loam
52	ADH02	7.390	0.048	2.145	0.948	18.141	6.905	0.043	76.0	14.0	10.0	Sandy Loam
53	ADH08	7.160	0.056	2.501	1.985	24.047	6.089	0.099	38.0	32.0	30.0	Clay loam
54	ADH04	6.680	0.023	2.145	1.267	26.558	6.231	0.059	28.0	42.0	30.0	Clay loam
55	MCTP02	6.850	0.043	2.208	1.374	13.818	9.526	0.073	46.0	36.0	18.0	Loam
56	MCTP02	7.300	0.085	2.145	1.676	26.558	5.557	0.069	42.0	26.0	32.0	Clay loam
57	ADH04	6.900	0.083	1.235	0.807	13.687	6.256	0.043	72.0	8.0	20.0	Sandy Loam
58	ADH08	6.590	0.480	2.733	0.995	17.958	5.671	0.046	76.0	6.0	18.0	Sandy Loam
UNITS			Ms/cm	%	%	Meq / 100gm soil	ppm	%	%			Class
METHOD CODE		MSL-M5.05-1	MSL-M5.05-2	MSL-M5.05-3	MSL-M5.05-4	MSL-M5.05-5	MSL-M5.05-6	MSL-M5.05-7	MSL-M5.05-8			

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Special Notes:
The ISO 17025Accredited methods are OC (MSL-M5.04-4), TN (MSL-M5.04-7) & (CEC MSL-M5.04-5)!

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ENAO Testing Laboratory T0021

TEST REPORT

Client Name; Tigray water works study Design & Supervision enterprise
Address; Mekelle
Attention:Atsbha G/anenya
Tel.: 0914004028
e-mail; --

Report No.: RMSL-0304/18
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Client Ref.: Your request for the lab. testing of samples
No. Samples:14 0f 167
Sample Type: Soil

Nominated Representative
G/Giorgis Aregai, *QA/QC Head*
Technical Signatories:
Girmay Hailu, Lab.Case team Head

For Administrative Case only
Name: G/medhine Berhe Responsibility: Centre Director Signature: Date:

Condition of samples:
This report relates specifically to the sample(s) tested in so far as that the sample(s) is truly representative of the sample delivered to our laboratory. All pages of this report have been checked and approved for release.

No.	Sample ID	Anayzed Parameters				
		Exch.Ca	Exch. Mg	Exch.K	Exch.Na	OM
45	MCTP03	9.400	4.000	81.600	26.600	1.164
46	ADH02	12.200	3.600	63.200	30.400	1.100
47	MCTP04	7.200	1.600	45.900	29.100	1.608
48	ADH06	4.400	5.600	38.700	30.800	1.114
49	ADH02	5.600	3.800	44.700	28.000	1.342
50	MCTP03	7.400	5.000	37.300	30.500	1.361
51	ADH04	5.200	2.800	34.600	28.000	1.249
52	ADH02	11.000	2.600	43.200	20.000	0.948
53	ADH08	5.400	3.200	33.400	27.500	1.985
54	ADH04	6.000	3.800	36.700	28.900	1.267
55	MCTP02	6.800	5.400	61.700	27.800	1.374
56	MCTP02	9.400	3.600	7.500	30.900	1.676
57	ADH04	4.200	2.200	31.600	27.900	0.807
58	ADH08	6.600	3.600	34.900	29.500	0.995
UNITS		Meq/L	Meq/L	ppm	ppm	%
METHOD CODE		***	***		***	***

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Special Notes:
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Girmay Hailu, Lab.Case team Head

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Name: G/medhine Berhe Responsibility: Centre Director Signature: Date:

Condition of samples:
This report relates specifically to the sample(s) tested in so far as that the sample(s) is truly representative of the sample delivered to our laboratory. All pages of this report have been checked and approved for release.

TEST REPORT

No.	Sample ID	Analyzed Parameters (Bulk Density)								
		BD								
45	MCTP03	2.445								
46	ADH02	2.282								
47	MCTP04	2.059								
48	ADH06	2.048								
49	ADH02	2.223								
50	MCTP03	2.318								
51	ADH04	2.437								
52	ADH02	2.363								
53	ADH08	2.104								
54	ADH04	1.964								
55	MCTP02	2.206								
56	MCTP02	2.247								
57	ADH04	2.347								
58	ADH08	2.223								
UNITS		** gm/cm³								
METHOD CODE		**								

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Special Notes:
The ISO 17025Accredited methods are OC (MSL-M5.04-4), TN (MSL-M5.04-7) & (CEC MSL-M5.04-5)!

REMARK- sample code ADH represents for river Chemiet