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Section-III: Investigation and Sectoral Studies

Volume-I: SOIL SURVEY and Land Suitability Evaluation Final Feasibility

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Feasibility Study and Detail Design of Omo Valley Farm Irrigation Project

Soil Survey and Land Suitability Evaluation

Final Feasibility Report

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PART-ONE: SOIL SURVEY REPORT

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Executive Summary

Omo Valley Farm Irrigation Project is found in South Omo Zone of Southern Nation Nationalities People Regional State (SNNPRS), at about 60 km west of Turmi village and about 950km from Addis Ababa. Most of the project area lies in Hamer Woreda, Karo Kebel. The command area of the project lies on the left side of the Omo River. The project area is part of Omo-Gibe River Basin bounded by geographic coordinates of 05° 10'N to 05° 16'N latitudes and 36° 12'E to 36° 17'E longitudes with altitude ranging from 385 to 450 m asl. The proposed command area covers a gross area of about 5,751.17 ha.

The soil survey is conducted at feasibility level to characterize and map the soils of the project area and evaluate their suitability for irrigation development. The soil survey methodology conducted by reviewing previous studies and other secondary data such as satellite image and topographic map before conducting the field survey. Field auger observation was conducted on 500 m X 500 m grid followed by soil profile examinations on representative sites. Disturbed and undisturbed soil samples were collected from representative profiles for laboratory analyses. Infiltration and hydraulic conductivity tests were conducted in the major soil mapping units. The soil investigation was carried out as described in the FAO (2006) guidelines for soil description and soils classification was done using the World Reference Base (WRB), version 2006, classification system.

The soils of the project area are delineated into eighteen soil mapping units (SMU). The SMUs were identified on the basis of slope, surface soil texture and major soil group. On the basis of morphological and chemical characteristics five major soil groups were identified, namely Fluvisols, Luvisols, Cambisols, Vertisols, and Arenosols.

The soils are very deep and the surface soil texture is dominantly sandy loam with association of fine to medium soil texture. The soils are dominantly none-sticky and none-plastic wet and generally well to somewhat excessively drain with various infiltration rates and permeability.

Most soils characterized by the presence of rock fragments though the degree of abundance, size and weathering stage varies. Mapping units 1SL-HFL, 2S-AR, and 2SL-FLCA have abundant rock fragments within the top 100 cm depth. This layer together with dominant medium to coarse texture is responsible for water loss via seepage in furrows. These properties downgrade the suitability class of most soils of the project area for surface irrigation. In these soils land preparation should be performed with great care to avoid deep plowing so that more rock fragments from sub surface layers will not be brought to the surface and hamper Cotton cultivation. However, some soils depict compacted layer/hard pan within the top 100 cm layer and hence require sub-soiling to break the compacted layer and these should be done with great care following the mapping unit/soil map of the command area.

Soils with high silt content in the surface, covers around 1100 ha have developed a surface crust/capping which inhibits infiltration and seed germination and increases run off. These soils require disking at regular intervals preferably before irrigation to promote infiltration. In addition, if these soils left dry for significant periods, then this increases soil loss through wind erosion and hence should not be left dry for long.

Crevasing is a common phenomenon in a stratified alluvial soil and hence the means to control this lie on not allowing water to enter the soil through cracks. Therefore prior to any development for irrigation the land must be leveled and present cracks filled in during land preparation and also the soils should be kept moist. Crevasing phenomenon can be minimized to acceptable levels but may not be fully overcome.

Stratification is a common feature of the command area soils. This stratification has implication for irrigation management. The different soil layers or horizons have widely differing textures and therefore water holding capacities that tend to change abruptly rather than gradually. This could result in water passing quickly through the coarse top soil and concentrating in a fine textured sub surface layer below the reach of the plant roots. This can cause also salt build up.

Soils of the study area are dominantly sub angular blocky on the surface. The bulk density values are higher than the acceptable range for agricultural soils and also imply there is compacted horizon within the soil solum.

The pH of the soils is slightly acid to neutral in the surface and slightly alkaline to very strongly alkaline in the subsurface horizons. The soils have medium to high cation exchange capacity-nutrient retention capacity and are dominantly low base saturated. There is no balanced proportion of the basic cations in the soils. In some soils the content of Mg relative to Ca is high and may inhibit Ca availability to crops and the content of Mg relative to K is high and may inhibit K uptake by crops. Similarly, most soils exhibit <2% K/CEC which implies K is below the critical value for tropical soils and implies the response of Cotton to K application is likely. Application of K should be in a split (half dose as basal application and half dose as top dressing application) to avoid K leaching in medium to coarse textured soils and K fixation in fine textured soils which is typical feature of soils in the command area.

The electrical conductivity of saturated paste extract of most of the surface soils is less than 2dS/m with no subsurface salinity risk. The exchangeable sodium percentages (ESP) of the soils are generally increases with soil depth and the values are lower than 10% (on pedon basis) implying none-sodic.

The available phosphorus content of the soils is high. However, the total nitrogen and organic carbon content of the soils are very low implying the need for N fertilization and application of organic matter. Available Fe and Mn content might not be deficient for Cotton production. Available Zn, Cu and B of most soils are marginal to deficient for Cotton.

In slightly to very strongly alkaline soils the levels of available Fe, Mn, Zn, Cu and Co are so low that plant growth is constrained and also available P can be reduced to a deficiency level. Hence, monitoring and control of macro (P) and micronutrients (Fe, Cu, Zn, Mn) availability, especially Fe (as Cotton is high Fe demanding crop), salinity and sodicity hazard as well as effect of K and Fe-fertilization trials are recommended.

As the site is characterized by high soil pH coupled with relatively high air temperature due attention should be given during N containing fertilizer selection and method of application to avoid loss of N due to volatilization.

There is common termite presence in the command area soils and hence termite management activities, which include integrated pest management, are highly recommended.

1. INTRODUCTION

1.1 Background

WWDSE has signed contract agreement with Omo Valley Farm Cooperation P.L.C to conduct the feasibility study and detailed design of Omo Valley Farm Irrigation Project which has a capacity of cultivating a gross area of 6,000 hectares of farm land. The irrigation project encompasses feasibility study and detail design for the gross irrigable area identified by the Client. The area lies in the lower reach of Omo river where the deep flowing river shows meandering pattern and necessitates lifting of the water.

This report presents the soils of Omo Valley Farm Irrigation Project studied between December 2014 to February 2015. The study includes soil survey at a gross area of 5,751.17 ha at an overall observation density of 1 per 25ha including soil sampling and physico-chemical properties measurement at representative mapping/land units.

1.2 Objectives

The overall objective of the soil survey is to provide detailed information on land and soils of the command area of the project at feasibility level as basis for confirming/rejecting irrigated Cotton cultivation. The study also focuses on identifying the various topographic forms, soil types, characteristics and distribution as a basis for assessment of irrigation suitability based on review and verification of previous studies and undertaking field survey. The specific objectives of the soil survey investigation were to:-

- Review previous soils and land resources study results around the Omo farm irrigation project area, and
- Investigate, identify, map at 1:10,000 scale, and describe the characteristics and distribution of different soil and terrain (land form) units of Omo valley farm irrigation project command area at feasibility level.

2. PHYSICAL ENVIRONMENT OF THE AREA

2.1 Location and Accessibility

Omo Valley Farm Irrigation Project is found in South Omo Zone of Southern Nation Nationalities People Regional State (SNNPRS), at about 60 km west of Turmi village and about 950km from Addis Ababa. Most of the project area lies in Hamer Woreda, KaroKebel.

The command area of the project lies on the left side of the Omo River. The project area is part of Omo-Gibe River Basin bounded by geographic coordinates of $05^{\circ} 10'N$ to $05^{\circ} 16'N$ latitudes and $36^{\circ} 12'E$ to $36^{\circ} 17'E$ longitudes with altitude ranging from 385 to 450 m asl. The proposed command area covers a gross area of about 5,751.17 ha.

3. PREVIOUS STUDIES

Semi-detailed soil surveys specifically for the presently proposed command area were not carried out so far. However, a reconnaissance soil study at 1:250,000 scale had been conducted in Omo-Gibe basin in 1995 specifically within the Lower Omo basin which includes the present Omo Valley Farm Cooperation Boundary. This study is of small scale with limitation to implement specific recommendation for Om Valley Farm Cooperation.

4. SURVEY METHODOLOGY

4.1 Pre-field Work

The pre-fieldwork stage is the inception and survey planning stage during which secondary data collection, review of previous studies and planning for the actual field data collection is done.

Review of previous studies: Review of the previous soil study of the project area was made from the Omo-Gibe basin master plan study. The review focused on the survey methodology, field and laboratory data, and findings. Short reconnaissance visit to the study area was made during this period.

Base Map Preparation: Slope and contour maps, generated from Land SAT TM 90 m resolution were reproduced to be used as a base map for field work. A preliminary delineation of approximate land unit boundaries using slope classes and gray tone differences as main criteria was undertaken as a guide to fix location of auger observation transects and representative pits locations.

4.2 Field Work

The field soil investigation was conducted in two successive steps:

Auger observation: The field verification investigation was carried out first by making auger soil observations on parallel fixed grids of 500 m apart laid across the land and auger observations were taken every 500 m along the grid line. The augerings were made with "Edelman" auger, to a depth of 1.25 m unless obstructed by lithic contact or stoniness. In some irregular units additional observations were made to study the variability due to irregular changes result from the direction of stream flow, deposition of transported material and gully areas presence.

A total of 240 auger observations were made and recorded on the standard auger description recording sheet. Following auger observation, preliminary soil mapping units were identified on the basis of slope, soil depth, surface soil texture, surface soil color and major soil group/soil type.

Profile sampling: For further soil characterization, soil profile pits were dug on representative sites. In this study a total of 24 soil profiles were described and of which 18 soil profiles were sampled depth wise from generic horizons for laboratory analysis.

In addition, total of 45 sub samples to make 5 composite samples were collected to supplement for soil fertility evaluation from 0 to 25 cm depth.

The soil profiles were described and the horizons were designated in situ according to the guidelines of FAO (2006). Soil colour notation was described according to Munsell Color Chart (KIC, 2000). The soils of the study site were classified according to World Reference

Base for Soil Resources (WRB, 2006) classification system. The names of the soils were determined following the 'key' to the classification system.

Soil profile pits were distributed across the study area to represent the identified major mapping units. Deep augurings were made to depth of 3 to 5 m and samples were also collected for laboratory analysis on the 4 sampled profiles to check the potential salinity and presence of sub surface impermeable layers.

A total of 77 disturbed soil samples, 13 deep auger samples and 11 undisturbed (pF-ring) samples were collected for laboratory analysis from the freshly dug pits. Four infiltration (IF) and hydraulic conductivity (HC) tests were made on representative sites using double ring infiltrometer and inverse auger hole method, respectively, in triplicates. Locations of auger observation points and profile pits are presented in Figure 4.1.

4.3 Post Fieldwork Stage

This is the final stage of the survey whereby the synthesis of the data and preparation of the soil survey report and soil map are accomplished. It includes:

Data Encoding: All the data collected during review of the previous studies and the present verification field-survey and laboratory results have been entered into a database in Microsoft Excel and Access for storage and data processing. The soil database consists of location and site description, soil horizon description, and soil physico-chemical properties.

Soil Database and GIS: The soil databases are linked to ARC GIS environment to combine the spatial and attribute features and generate soil-landscape map.

Data Elaboration and Manipulation: In order to characterize properly the final soil-mapping units, the soil databases were checked and all the field observation points (profile pits and auger holes) were plotted in the digital map. All homogeneous observations within one mapping unit used to characterize that specific mapping unit.

Legend Construction and Map Compilation: The soil mapping units' legend constructed using slope, soil depth, surface soil texture, surface soil color and major soil group/soil type.

Location map of the different soil observation sites, detailed mapping units and soil map digitized and produced at the scale of 1:10,000 with extended legend from the data collected during the present field survey.

4.4 Laboratory Analyses

The soil samples were analyzed in laboratory for the following parameters:-

- Particle size distribution by hydrometer method.
- Electrical conductivity and soil pH in 1:2.5 soil to water suspension.
- Cation exchange capacity (CEC) by the ammonium acetate (pH 7) method.

- Exchangeable basic cations (Ca, Mg, K, Na) content from the ammonium acetate leachate.
- CaCO_3 content by HCl dissolution method.
- Total nitrogen by the Kjeldhal method.
- Available phosphorus by the Olsen method.
- Organic carbon (OC) by the Walkley and Black method.
- Bulk density (BD) on dry weight basis from pF-ring samples.
- Moisture content (FC and PWP) by pressure plate extraction.
- Soil porosity (SP) on the basis of bulk density and FC.
- Base saturation (BS) is computed as $\frac{\sum(Ca + Mg + K + Na)}{CEC} \times 100$
- Exchangeable sodium percentage (ESP) is computed as $\frac{Na}{CEC} \times 100$
- Available micronutrients (Fe, Cu, Zn, Mn) by DTPA extracting solution
- Boron by hot water extraction

Figure 4.1 Locations of auger observation points

4.5 Soil Mapping Units and Classification

After completion of the field work, compilation and encoding of field observation and laboratory data was carried out. The data was analyzed for various soil properties and the preliminary field soil mapping unit was rectified accordingly.

Slope, surface soil texture, and major soil group were used to identify the different major soil mapping units (Table 4.1).

The four characters of the soil mapping unit symbol (e.g. 1SL-HFL) is explained as follows: The first Arabic number (1) represents the slope class, the upper case letter/s/ (SL) represents the surface soil texture, and the last three upper case letters (HFL) in combination represents the soil type. For instance soil mapping unit code: 1SL-HFL= Slope 0-1%; Surface soil texture=Sandy Loam; and soil type = Haplic Fluvisols

Accordingly, fifty one mapping units have been identified in the project area (Table 4.2). The soil mapping unit and soil map of the project area is presented at 1:10,000 scale in separate sheets. On the basis of field profile descriptions and laboratory results, the soils were identified and classified at soil unit level according to the WRB (2006) soil classification system.

Table 4.1.Distinguishing criteria of the mapping units

Slope %		Surface Soil Texture (0–30cm)				Major Soil Group	
Class	Code	Type	Code	Type	Code	Soil Type	Code
0 - 2	1	Heavy clay	HC	Silty clay loam	SiCL	Fluvisols	FL
2 - 4	2	Clay	C	Silt loam	SiL	Cambisols	CA
4 - 6	3	Silty clay	SiC	Sandy clay loam	SCL	Vertisols	VR
6 - 8	4	Sandy clay	SC	Sandy Loam	SL	Luvisols	LV
		Silt	Si	Loamy sand	LS		
		Loam	L	Sand	S		

Table 4.2: Soil mapping units and dominant soil types of the study area

SMU	Map Code	Major Soil Unit (WRB,2006)	Representative Pedon	Area	
				ha	%
1C-HLV	1	Haplic Luvisols	Ovp-3	123.93	2.15
1C-MVR	2	Mollic Vertisols	Ovp-7	226.74	3.94
1C-VrLV	3	Vertic Luvisols	-	200.24	3.48
1CL-HFL	4	Haplic Fluvisols (siltic)	Ovp-15	33.31	0.58
1L-HFL	5	Haplic Fluvisols	-	15.21	0.26
1L-MFL	6	Mollic Fluvisols	Ovp-8	55.62	0.97
1L-VrLV	7	Vertic Luvisols (Manganiferic)	Ovp-22	40.27	0.70
1LS-HFL	8	Haplic Fluvisols	Ovp-6, Ovp-17,	937.94	16.31
1LS-MVR	9	Mollic Vertisols	-	17.19	0.30
1LS-UFL	10	Umbric Fluvisols	-	45.75	0.80
1S-HAR	11	Haplic Arenosol (Dystric)	Ovp-16	77.30	1.34
1S-HFL	12	Haplic Fluvisols	Ovp-10, Ovp-14	259.56	4.51
1SC-FLCA	13	Fluvic Cambisols	-	31.26	0.54
1SC-HFL	14	Haplic Fluvisols	-	60.66	1.05
1SC-HLV	15	Haplic Luvisols	-	63.65	1.11
1SC-MVR	16	Mollic Vertisols	-	210.13	3.65
1SC-VrLV	17	Vertic Luvisols	-	138.50	2.41
1SCL-FLCA	18	Fluvic Cambisols	Ovp-4	169.65	2.95
1SCL-HFL	19	Haplic Fluvisols	-	247.66	4.31
1SCL-HLV	20	Haplic Luvisols	-	30.74	0.53
1SCL-MFL	21	Mollic Fluvisols	Ovp-12	82.44	1.43
1SL-FLCA	22	Fluvic Cambisols	Ovp-5;Ovp-21	286.22	4.98
1SL-HAR	23	Haplic Arenosol (Dystric)	-	70.63	1.23
1SL-HFL	24	Haplic Fluvisols	Ovp-24	152.60	2.65
1SL-HLV	25	Haplic Luvisols (Dystric, Siltic)	Ovp-11	96.40	1.68
1SL-MFL	26	Mollic Fluvisols	-	10.71	0.19
1SL-MVR	27	Mollic Vertisols	-	33.89	0.59
1SL-UFL	28	Umbric Fluvisols	Ovp-1	25.48	0.44
1SL-VrLV	29	Vertic Luvisols	-	47.56	0.83
1SiC-CLV	30	Cutanic Luvisols (Manganiferic)	Ovp-9	37.82	0.66
1SiC-HFL	31	Haplic Fluvisols	-	517.37	9.00
1SiC-HLV	32	Haplic Luvisols	-	49.53	0.86
1SiC-MVR	33	Mollic Vertisols	-	28.07	0.49
1SiC-VrLV	34	Vertic Luvisols	Ovp-18;Ovp-19;Ovp-23	474.53	8.25
2C-VrLV	35	Vertic Luvisols	-	10.49	0.18
2LS-HFL	36	Haplic Fluvisols	-	12.28	0.21
2LS-UFL	37	Umbric Fluvisols	Ovp-2	19.85	0.35
2S-HAR	38	Haplic Arenosol (Dystric)	Ovp-16	27.71	0.48
2S-HFL	39	Haplic Fluvisols	Ovp-10	46.79	0.81
2SC-HFL	40	Haplic Fluvisols	-	41.47	0.72
2SC-VrLV	41	Vertic Luvisols	-	14.67	0.26

SMU	Map Code	Major Soil Unit (WRB,2006)	Representative Pedon	Area	
				ha	%
2SCL-FLCA	42	Fluvic Cambisols	-	20.87	0.36
2SCL-HFL	43	Haplic Fluvisols	-	21.47	0.37
2SL-FLCA	44	Fluvic Cambisols (Eutric)	Ovp-20	75.14	1.31
2SL-HAR	45	Haplic Arenosols (Dystric)	-	15.31	0.27
2SL-HFL	46	Haplic Fluvisols	Ovp-13	327.95	5.70
2SiC-HFL	47	Haplic Fluvisols	-	37.54	0.65
2SiC-VrLV	48	Vertic Luvisols	-	10.83	0.19
3SCL-FLCA	49	Fluvic Cambisols	-	31.10	0.54
3SL-HFL	50	Haplic Fluvisols	-	51.32	0.89
4SL-HFL	51	Haplic Fluvisols	-	87.85	1.53
Total				5751.17	100.00

Figure 4.2: Soil –landscape unit map

5. SOILS OF THE PREOJECT AREA

5.1 Major Soil Types in the Project Area

Four major soil groups: Fluvisols, Cambisols, Luvisols, Vertisols and Arenosols are identified in the project command area.

5.2 Description of Soil Mapping Units

The identified SMUs of the study area are presented in Figure 4.2. Description of the SMUs is given below.

1C-HLV

This unit refers to the fine textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are moderately well drained; Very deep; Very dark brown (7.5YR2.5/3, moist); clayey on the surface and weakly compacted between 27 to 60 cm.

The pH of the surface and sub-surface soils is 6.21 (neutral) to 7.95 (slightly alkaline) respectively. The soils are none saline throughout the profile. The ESP values of the soils within one meter depth is less than six (implying none-sodic) and the CaCO_3 percentage ranges from 4 to 8 within the profile.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 40.35 cmolc kg⁻¹ (high) in the surface and it is low base saturated, dominantly by Ca followed by Mg, K and Na.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 3.0 and 13.14 respectively; implying very favorable and favorable for crop production respectively. The surface soils K/CEC ratio is <2% which implies below the minimum K level for tropical soils.

The available phosphorus content of the surface soils is 24.05 mg/kg of soil (high). The organic carbon and total nitrogen content of the surface soils are 0.87 % (very low) and 0.11 % (low), respectively.

The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 29.58, 14.34, 1.37, 0.015 and 0.052 mg/kg soil, respectively.

The total extent of the unit is 123.92 ha and Haplic Luvisols are the dominant soil type of the unit.

1C-MVR

This unit refers to the fine textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are poor; very deep; dark brown, 7.5YR3/4; clayey in the surface and weakly compacted within 30 to 90 cm depth.

The pH of the surface and sub-surface soils is 6.85 (neutral) to 7.88 (slightly alkaline) respectively. The soils are none saline throughout the profile. The ESP value of the soils within one meter depth is less than four (implying none- sodic). The CaCO_3 percentage ranges from 4 to 8 within the profile.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 60.14Cmolc kg⁻¹ (very high) in the surface and it is highly base saturated, dominantly by Ca followed by Mg, K and Na.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 2.84 and 7.68 respectively; implying very favorable and favorable for crop production respectively. The surface soils K/CEC ratio is <2% which implies below the minimum K level for topical soils.

The available phosphorus content of the surface soils is 27.32 mg/kg of soil (high). The organic carbon and total nitrogen content of the surface soils are 1.83 % (very low) and 0.21% (medium), respectively. The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 21.84, 13.41, 0.91, 5.48 and 0.61mg/kg soil, respectively.

The total extent of the unit is 226.74 ha and Mollic Vertisols are the dominant soil type of the unit.

1CL-HFL

This unit refers to the fine textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are Moderately well drained; very deep; dark yellowish brown (10YR3/4, moist); clay loam in the surface and none compacted and none cemented throughout the profile.

The pH of the surface and sub-surface soils is 7.05 (neutral) to 7.85 (slightly alkaline) respectively. The soils are none saline throughout the profile. The ESP values of the soils within one meter depth is less than three (implying none- sodic). However, a slightly higher ESP value 19 is observed between 180 and 200cm depth. The CaCO_3 percentage ranges from 3 to 8 within the profile.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 50.6Cmolc kg⁻¹ (high) in the surface and it is highly base saturated, dominantly by Ca followed by Mg, Na and K.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 3.1 and 6.8 respectively; implying very favorable and favorable for crop production respectively. The surface soils K/CEC ratio is >2% which implies above the minimum K level for topical soils.

The available phosphorus content of the surface soils is 12.72 mg/kg of soil (high). The organic carbon and total nitrogen content of the surface soils are 1.21 % (very low) and 0.08 % (low), respectively.

The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 17.61, 3.14, 3.31, 0.08 and 0.67mg/kg soil, respectively.

The total extent of the unit is 33.31 ha and Haplic Fluvisols (siltic) are the dominant soil type of the unit.

1L-MFL

This unit refers to the medium textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are moderately well drained; very deep; dark brown (7.5YR3/3, moist); loam in the surface and weakly compacted within 20 to 70 cm depth of the profile.

The pH of the surface and sub-surface soils is 6.77 (neutral) to 8.15 (strongly alkaline) respectively. The soils are none saline throughout the profile. The ESP value of the soils within one meter depth is less than six (implying none- sodic). The CaCO_3 percentage ranges from 1.13 to 8.3 below the surface layer though it is trace in the surface.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 28.82Cmolc kg-1 (high) in the surface and it is highly base saturated, dominantly by Ca followed by Mg, Na and K.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 2.92 and 7.74 respectively; implying very favorable and favorable for crop production respectively. The surface soils K/CEC ratio is <2% which implies below the minimum K level for tropical soils.

The available phosphorus content of the surface soils is 21.9 mg/kg of soil (high). The organic carbon and total nitrogen content of the surface soils are 0.6 % (very low) and 0.085 % (low), respectively.

The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 21.26, 22.46, 2.7, 2.89 and 0.065mg/kg soil, respectively.

The total extent of the unit is 55.62 ha and Mollic Fluvisols are the dominant soil type of the unit.

1SCL-FLCA

This unit refers to the medium textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are moderately well drained; very deep; dark brown (7.5YR3/3, moist); sandy clay loam in the surface. The soils are characterized by weak compaction between 44 to 100 cm and presence of common fresh rock fragments between 150 to 200 cm depth.

The pH of the surface and sub-surface soils is 6.7 (neutral) to 7.55 (slightly alkaline) respectively. The soils are none saline throughout the profile. The ESP value of the soils within one meter depth is less than four (implying none- sodic). The CaCO_3 percentage ranges from 0.84 to 1.75 below the surface layer though it is trace in the surface.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 42.99Cmolc kg-1 (very high) in the surface and it is highly base saturated, dominantly by Ca followed by Mg, Na and K.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 3.16and 9.08 respectively; implying very favorable and favorable for crop production respectively. The surface soils K/CEC ratio is <2% which implies below the minimum K level for topical soils.

The available phosphorus content of the surface soils is 26.36 mg/kg of soil (high).The organic carbon and total nitrogen content of the surface soils are 0.49 % (very low) and 0.069 % (low), respectively.

The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 16.48, 10.28, 2.63, 2.67 and 0.064mg/kg soil, respectively.

The total extent of the unit is 169.65 ha and Fluvisols are the dominant soil type of the unit.

1SCL-MFL

This unit refers to the medium textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are moderately well drained; very deep; dark brown (7.5YR3/3, moist); sandy clay loam in the surface and weakly compacted between 90 to 120 cm.

The pH of the surface and sub-surface soils is 6.86 (neutral) to 7.07 (slightly alkaline) respectively. The soils are none saline throughout the profile. The ESP value of the soils within one meter depth is less three (implying none- sodic). The CaCO₃ percentage ranges from 2.44 to 6.59throughout the profile.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 34.59Cmolc kg-1 (high) in the surface and it is highly base saturated, dominantly by Ca followed by Mg, K and Na.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 3.07and 4.64 respectively; implying very favorable and favorable for crop production respectively. The surface soils K/CEC ratio is >2% which implies above the minimum K level for topical soils.

The available phosphorus content of the surface soils is 26.6 mg/kg of soil (high).The organic carbon and total nitrogen content of the surface soils are 1.00 % (very low) and 0.049 % (low), respectively.

The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 15.32, 19.14, 31.57, 2.62and 0.43mg/kg soil, respectively.

The total extent of the unit is 82.44 ha and MollicFluvisolsare the dominant soil type of the unit.

1SiC-CLV

This unit refers to the fine textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are moderately well drained; Very deep; dark brown (7.5YR 3/4, moist); silty clay on the surface and weakly compacted between 20 to 110 cm. These soils are characterized by presence of few slightly weathered rock fragments between 110 to 160 cm depth.

The total extent of the unit is 37.82 ha and Cutanic Luvisols (Manganiferic) are the dominant soil type of the unit.

1SiC-VrLV

This unit refers to the fine textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are imperfectly drained; very deep; dark brown (7.5YR3/4, moist) to dark yellowish brown (10YR3/6, moist); silty clay in the surface and weakly compacted within 20 to 100 cm depth. The soils have common slightly weathered rock fragments between 155 to 200 cm soil depth.

The pH of the surface and sub-surface soils is 6.87 (neutral) to 7.9 (slightly alkaline) respectively. The soils are none saline throughout the profile. The ESP value of the soils within one meter depth is less than four (implying none- sodic). The CaCO_3 percentage ranges from 2.33 to 8.18 within the profile.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 86.36 cmolc kg⁻¹ (very high) in the surface and it is low base saturated, dominantly by Ca followed by Mg, K and Na.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 3.0 and 3.04 respectively; implying very favorable for crop production. The surface soils K/CEC ratio is <2% which implies below the minimum K level for topsoils.

The available phosphorus content of the surface soils is 22.14 mg/kg of soil (high). The organic carbon and total nitrogen content of the surface soils are 0.67 % (very low) and 0.014% (low), respectively. The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 16.75, 19.87, 2.6, 0.09 and 0.4 mg/kg soil, respectively.

The total extent of the unit is 474.53 ha and Vertic Luvisols and Vertic Luvisols Manganiferic are the dominant soil type of the unit.

1SL-FLCA

This unit refers to the medium to coarse textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are moderately well drained; moderately deep (pedon Ovp- 21) to very deep; dark brown (7.5YR3/4, moist); sandy loam in the surface. This unit represented by pedon Ovp-5 has weakly compacted layer between 25 to 100 cm and 165-200 cm depth. Rock fragments abundance and degree of weathering ranges from very

few fresh (pedon Ovp-5; 165-200cm depth) to common slightly weathered (pedon Ovp-21; 67-200 cm depth).

The pH of the surface and sub-surface soils is 7.2 (neutral) to 8.33 (slightly alkaline) respectively. The soils are none saline throughout the profile. The ESP value of the soils within one meter depth is less than six (implying none- sodic). The CaCO_3 percentage ranges from 0.82 to 5.6 within the profile.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 16.96Cmolc kg-1 (very high) in the surface and it is highly base saturated, dominantly by Ca followed by Mg, K and Na.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 3.0and 3.8 respectively; implying very favorable for crop production. The surface soils K/CEC ratio is >2% which implies above the minimum K level for topical soils.

The available phosphorus content of the surface soils is 15.55 mg/kg of soil (high).The organic carbon and total nitrogen content of the surface soils are 0.4 % (very low) and 0.021% (low), respectively. The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 9.35, 5.23, 1.14, 0.032 and 0.1mg/kg soil, respectively.

The total extent of the unit is 286.22 ha and Fluvisols are the dominant soil type of the unit.

1LS-HFL

This unit refers to the medium to coarse textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are moderately well drained; very shallow (pedon Ovp- 6) to very deep; brown (7.5YR4/2, moist) to dark grayish brown (10YR4/2); loamy sand in the surface. Rock fragments abundance and degree of weathering varies with the representative pedons: common fresh (24-72 cm) and abundant slightly weathered (72-200 cm) in pedon Ovp-6; few slightly weathered (40-64 cm) and common slightly weathered (125-200 cm) in pedon Ovp-17.

The pH of the surface and sub-surface soils is 6.85 (neutral) to 8.3 (strongly alkaline) respectively. The soils are none saline throughout the profile. The ESP value of the soils within one meter depth is less than six (implying none- sodic). The CaCO_3 percentage ranges from 0.82 to 5.6 within the profile.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 36.88Cmolc kg-1 (very high) in the surface and it is low base saturated, dominantly by Ca followed by Mg, K and Na.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 2.75and 5.03 respectively; implying very favorable and favorable for crop production. The surface soils K/CEC ratio is <2% which implies below the minimum K level for topical soils.

The available phosphorus content of the surface soils is 22.94 mg/kg of soil (high).The organic carbon and total nitrogen content of the surface soils are 0.44 % (very low) and

0.049% (low), respectively. The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 10.07, 3.19, 1.14, 0.63 and 0.12mg/kg soil, respectively.

The total extent of the unit is 937.94 ha and Haplic Fluvisols are the dominant soil type of the unit.

1SL-HLV

This unit refers to the medium textured soils, occurring mainly on a very gently sloping plain (0 to 2% slopes). The soils are moderately well drained; very deep; dark brown (7.5YR 3/4, moist); sandy loam on the surface and weakly compacted between 20 to 70 cm. These soils are characterized by presence of few slightly weathered rock fragments between 110 to 150 cm depth.

The total extent of the unit is 96.4 ha and Haplic Luvisols (Dystric,Siltic) are the dominant soil type of the unit.

2LS-UFL

This unit refers to the medium textured soils, occurring mainly on a gently sloping (2 to 4% slopes). The soils are somewhat excessively drained; very deep; dark yellowish brown (10YR 3/6, moist); loamy sand on the surface. These soils are characterized by presence of few fresh rock fragments between 135 to 159 cm depth.

The pH of the surface and sub-surface soils is 6.95 (neutral) to 7.38 (slightly alkaline) respectively. The soils are none saline throughout the profile. The ESP values of the soils within one meter depth ranges from 0.52 to 2.37 implying none-sodic.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 31.74 Cmolc kg⁻¹ (high) in the surface and it is low base saturated, dominantly by Ca followed by Mg, K and Na.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 3.0and 4.59, respectively, implying very favorable for crop production. The surface soils K/CEC ratio is <2% which implies below the minimum K level for topical soils.

The available phosphorus content of the surface soils is 24.05 mg/kg of soil (high).The organic carbon and total nitrogen content of the surface soils are 0.61 % (very low) and 0.05 % (low), respectively. The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 21.83, 6.18, 1.0, 0.87 and 0.033mg/kg soil, respectively.

The total extent of the unit is 19.85 ha and Haplic Fluvisols are the dominant soil type of the unit.

1L-VrLV

This unit refers to the medium textured soils, occurring mainly on a gently sloping (2 to 4% slopes). The soils are imperfectly drained; very deep; dark brown (10YR 3/3, moist); loam on

the surface and weakly compacted between 65 to 122 cm. These soils are characterized by presence of common slightly weathered rock fragments between 160 to 200 cm depth.

The pH of the surface and sub-surface soils is 6.75 (neutral) and 7.02 (neutral) respectively. The soils are none saline throughout the profile. The ESP values of the soils within one meter depth ranges from 1.11 to 2.43 implying none-sodic. The CaCO_3 percentage ranges from 1.85 to 4.56 below the top layer.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 33.7 Cmolc kg^{-1} (high) in the surface and it is highly base saturated, dominantly by Ca followed by Na and K.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 4.33 and 8.9, respectively; implying very favorable and favorable for crop production. The surface soils K/CEC ratio is <2% which implies below the minimum K level for topical soils.

The available phosphorus content of the surface soils is 29.75 mg/kg of soil (high). The organic carbon and total nitrogen content of the surface soils are 0.85 % (very low) and 0.04 % (low), respectively. The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 15.53, 49.34, 1.82, 0.08 and 0.32 mg/kg soil, respectively.

The total extent of the unit is 40.27 ha and Vertic Luvisols (Manganiferic) are the dominant soil type of the unit.

1S-HAR

This unit refers to the medium textured soils, occurring mainly on a gently sloping plain (2 to 4% slopes). The soils are excessively rapid; shallow; brown (7.5YR 4/2. moist); and sandy throughout the profile. The soils have common (0-25) to abundant (25-200 cm) rock fragments.

The pH of the surface and sub-surface soils is 7.2 (neutral) to 6.87 (neutral) respectively. The soils are none saline throughout the profile. The ESP value of the soils within one meter depth is less than three (implying none-sodic). The CaCO_3 percentage ranges from 2.24 to 5.4 throughout the profile.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 26.08 Cmolc kg^{-1} (high) in the surface and it is low base saturated, dominantly by Ca followed by Mg, Na and K.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 2.0 (low Ca) and 8.9 (favorable for crop production) respectively. The surface soils K/CEC ratio is <2% which implies below the minimum K level for topical soils.

The available phosphorus content of the surface soils is 6.92 mg/kg of soil (low). The organic carbon and total nitrogen content of the surface soils are 0.65 % (very low) and 0.035 % (low), respectively.

The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 6.7, 4.92, 1.08, 0.02 and 0.11 mg/kg soil, respectively.

The total extent of the unit is 27.71 ha and Haplic Arenosols (Dystric) are the dominant soil type of the unit.

1S-HFL

This unit refers to the medium textured soils, occurring mainly on a gently sloping plain (2 to 4% slopes). The soils are excessively rapid; very deep; dark yellowish brown (7.5YR 4/1. moist); and sandy in the surface. The soils have common slightly weathered (30-90 cm) rock fragments.

The pH of the surface and sub-surface soils is 6.97 (neutral) to 8.06 (slightly alkaline) respectively. The soils are none saline throughout the profile. The ESP value of the soils within one meter depth is less than three (implying none- sodic). The CaCO₃ percentage ranges from 4.8 to 5.8 below the top layer.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 39.08 cmolc kg⁻¹ (high) in the surface and it is low base saturated, dominantly by Ca followed by Mg, Na and K.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 3.0 (very favorable for crop production) and 6.0 (favorable for crop production) respectively. The surface soils K/CEC ratio is <2% which implies below the minimum K level for tropical soils.

The available phosphorus content of the surface soils is 27.0 mg/kg of soil (high). The organic carbon and total nitrogen content of the surface soils are 0.48 % (very low) and 0.035 % (low), respectively.

The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 11.2, 4.12, 2.23, 1.1 and 0.23 mg/kg soil, respectively.

The total extent of the unit is 46.79 ha and Haplic Fluvisols are the dominant soil type of the unit.

2SL-FLCA

This unit refers to the medium textured soils, occurring mainly on a gently sloping plain (2 to 4% slopes). The soils are well drained; moderately deep; dark brown (10YR 3/3, moist); and sandy loam in the surface. The soils have few slightly weathered (25-66 cm), abundant slightly weathered (66-124), and few slightly weathered (124-200) rock fragments.

The pH of the surface and sub-surface soils is 7.56 (slightly alkaline) to 8.45 (strongly alkaline) respectively. The soils are none saline throughout the profile. The ESP value of the soils within one meter depth is less than five (implying none- sodic). The CaCO₃ percentage ranges from 3.5 to 5.25.

The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 16.52Cmolc kg-1 (medium) in the surface and it is low base saturated, dominantly by Ca followed by Mg, Na and K.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 3.0 (very favorable for crop production) and 4.48 (very favorable for crop production) respectively. The surface soils K/CEC ratio is >2% which implies above the minimum K level for topical soils.

The available phosphorus content of the surface soils is 4.0 mg/kg of soil (low). The organic carbon and total nitrogen content of the surface soils are 0.56 % (very low) and 0.035 % (low), respectively.

The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 9.8, 4.6, 0.75, 0.06 and 0.4 mg/kg soil, respectively.

The total extent of the unit is 75.14 ha and Fluvisols (Eutric) are the dominant soil type of the unit.

2SL-HFL

This unit refers to the medium textured soils, occurring mainly on a gently sloping plain (2 to 4% slopes). The soils are moderately well drained; very deep; Dark yellowish brown (10YR3/4, moist); sandy loam on the surface. These soils are characterized by presence of common fresh rock fragments between 100 to 200 cm depth.

The total extent of the unit is 327.95 ha and Haplic Fluvisols are the dominant soil type of the unit.

1SL-UFL

This unit refers to the medium textured soils, occurring mainly on a gently sloping plain (0 to 2% slopes). The soils are moderately well drained; very deep; dark brown (10YR3/6, moist); sandy loam on the surface. These soils are characterized by presence of few fresh rock fragments between 36 to 96 cm depth.

The pH of the surface and subsurface soils is 6.3 (slightly acid) and 7.25 (slightly alkaline) respectively. The soils are none saline throughout the profile. The ESP values of the soils within one meter depth ranges from 2.0 to 2.8 (none-sodic). The cation exchange capacity (CEC) - nutrient retention capacity of the soil is 39.5Cmolc kg-1 (low) in the surface and it is low base saturated, dominantly by Ca followed by Mg, Na, and K.

The ratio of exchangeable Ca to Mg and Mg to K in the surface soils is 2.1 (implying low Ca) and 23.45 (high Mg to suppress K uptake), respectively. The surface soils K/CEC ratio is <2% which implies below the minimum K level for topical soils.

The available phosphorus content of the surface soils is 26.46 mg/kg of soil (high). The organic carbon and total nitrogen content of the surface soils are 0.82 % (very low) and 0.09 % (low), respectively. The amount of available micronutrients - Fe, Mn, Zn, Cu and B in the surface soils is 31.14, 19.29, 2.31, 1.25 and 0.03 mg/kg soil, respectively.

The total extent of the unit is 25.48 ha and Umbric Fluvisols are the dominant soil type of the unit.

1C-VrLV

The same as 1SiC-VrLV except the surface soil texture class. The total extent of the unit is 200.24 ha and Vertic Luvisols are the dominant soil type of the unit.

1L-HFL

The same as 2SL-HFL except the surface soil texture and slope class. The total extent of the unit is 15.21 ha and Haplic Fluvisols are the dominant soil type of the unit.

1LS-MVR

The same as 1C-MVR except the surface soil texture class. The total extent of the unit is 17.19 ha and Mollic Vertisols are the dominant soil type of the unit.

1LS-UFL

The same as 1SL-UFL except the surface soil texture class. The total extent of the unit is 45.75 ha and Umbric Fluvisols are the dominant soil type of the unit.

1SC-FLCA

The same as 1SCL-FLCA except the surface soil texture class. The total extent of the unit is 31.26 ha and Fluvic Cambisols are the dominant soil type of the unit.

1SC-HFL

The same as 2SL-HFL except the surface soil texture and slope class. The total extent of the unit is 15.21 ha and Haplic Fluvisols are the dominant soil type of the unit.

1SC-HLV

The same as 1SL-HLV except the surface soil texture class. The total extent of the unit is 63.65 ha and Haplic Luvisols are the dominant soil type of the unit.

1SC-MVR

The same as 1C-MVR except the surface soil texture class. The total extent of the unit is 210.13 ha and Mollic Vertisols are the dominant soil type of the unit.

1SC-VrLV

The same as 1SiC-VrLV except the surface soil texture class. The total extent of the unit is 138.50 ha and Vertic Luvisols are the dominant soil type of the unit.

1SCL-HFL

The same as 2SL-HFL except the surface soil texture and slope class. The total extent of the unit is 247.66 ha and Haplic Fluvisols are the dominant soil type of the unit.

1SCL-HLV

The same as 1SL-HLV except the surface soil texture class. The total extent of the unit is 30.74 ha and Haplic Luvisols are the dominant soil type of the unit.

1SL-HAR

The same as 1S-HAR except the surface soil texture class. The total extent of the unit is 70.63 ha and Haplic Arenosols are the dominant soil type of the unit.

1SL-MFL

The same as 1L-MFL except the surface soil texture class. The total extent of the unit is 10.7 ha and Mollic Fluvisols are the dominant soil type of the unit.

1SL-MVR

The same as 1C-MVR except the surface soil texture class. The total extent of the unit is 33.89 ha and Mollic Vertisols are the dominant soil type of the unit.

1SL-VrLV

The same as 1SiC-VrLV except the surface soil texture class. The total extent of the unit is 47.56 ha and Vertic Luvisols are the dominant soil type of the unit.

1SiC-HFL

The same as 2SL-HFL except the surface soil texture and slope class. The total extent of the unit is 517.37 ha and Haplic Fluvisols are the dominant soil type of the unit.

1SiC-HLV

The same as 1SL-HLV except the surface soil texture class. The total extent of the unit is 49.53 ha and Haplic Luvisols are the dominant soil type of the unit.

1SiC-MVR

The same as 1C-MVR except the surface soil texture class. The total extent of the unit is 28.06 ha and Mollic Vertisols are the dominant soil type of the unit.

2C-VrLV

The same as 1SiC-VrLV except the surface soil texture and slope class. The total extent of the unit is 10.49 ha and Vertic Luvisols are the dominant soil type of the unit.

2LS-HFL

The same as 1LS-HFL except the surface soil texture and slope class . The total extent of the unit is 12.3 ha and Haplic Fluvisols are the dominant soil type of the unit.

2S-HAR

The same as 1S-HAR except the slope class. The total extent of the unit is 70.63 ha and Haplic Arenosols are the dominant soil type of the unit.

2SC-HFL

The same as 2SL-HFL except the surface soil texture class . The total extent of the unit is 41.5 ha and Haplic Fluvisols are the dominant soil type of the unit.

2SC-VrLV

The same as 1SiC-VrLV except the surface soil texture and slope class. The total extent of the unit is 14.67 ha and Vertic Luvisols are the dominant soil type of the unit.

2SCL-FLCA

The same as 1SCL-FLCA except the surface soil texture and slope class. The total extent of the unit is 20.9 ha and Fluvic Cambisols are the dominant soil type of the unit.

2SCL-HFL

The same as 2SCL-HFL except the surface soil texture class . The total extent of the unit is 21.5 ha and Haplic Fluvisols are the dominant soil type of the unit.

2SL-HAR

The same as 1S-HAR except the surface texture and slope class. The total extent of the unit is 15.3 ha and Haplic Arenosols are the dominant soil type of the unit.

2SiC-HFL

The same as 2SL-HFL except the surface soil texture class. The total extent of the unit is 37.5 ha and Haplic Fluvisols are the dominant soil type of the unit.

2SiC-VrLV

The same as 1SiC-VrLV except the surface soil texture and slope class. The total extent of the unit is 10.8 ha and Vertic Luvisols are the dominant soil type of the unit.

3SCL-FLCA

The same as 1SCL-FLCA except the surface soil texture and slope class. The total extent of the unit is 31.1 ha and Fluvisols are the dominant soil type of the unit.

3SL-HFL

The same as 2SL-HFL except the surface soil texture and slope class. The total extent of the unit is 51.3 ha and Haplic Fluvisols are the dominant soil type of the unit.

4SL-HFL

The same as 2SL-HFL except the surface soil texture and slope class. The total extent of the unit is 87.8 ha and Haplic Fluvisols are the dominant soil type of the unit.

6. PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOILS

6.1 Soil Physical Characteristics

Physical characteristics of representative profiles are given in Table 6.1 and a guide for physical data interpretation is given in Appendix table 2.

6.1.1 Soil Texture and Rock Fragments

The dominant surface soil textural group is sandy loam. In addition sandy soil texture throughout the profile is observed in 2S-HAR mapping unit. Most soils contain rock fragments within their profile with various degrees of abundance, size and weathering stage. Accordingly, an abundant rock fragment within the top 100 cm layer is observed in 1SL-HFL, 2S-HAR, and 2SL-FLCA mapping units and others are characterized by few to common slightly weathered rock fragments at various depths (Table 6.1). This condition limits the effective soil depth of these units for cotton cultivation. The medium to coarse texture nature coupled with presence of rock fragments is responsible for rapid water removal within the soils and hence downgrade the suitability class of most soils of the project area for surface irrigation. It is impossible to ensure uniform water distribution within each farm block of soils using surface irrigation method in 2S-HAR mapping units.

Soils with high silt content have developed a surface crust as a result of rain drop impact and in time forms a hard crust/capping which inhibits infiltration and seed germination and increases run off. These soils require discing at regular intervals preferably before irrigation to promote infiltration. The other danger with these soils is that if they left dry for significant periods, then this increases soil loss through wind erosion and hence should not be left dry for long.

Stratified alluvial soils are the dominant soils in the command area and in these soils surface cracks and sinkholes have been observed. Whenever water enters through cracks and sinkholes and rapidly erodes the coarser textured layers in the soil profile can cause the soil to collapse from above which is called crevassing phenomenon. The means to control the problem lies on not allowing water to enter the soil through cracks. Therefore prior to any development for irrigation the land must be leveled and present cracks filled in during land

preparation. The other possible solution is to keep the soil moist. Crevassing phenomenon is doubtful to fully overcome but only can be minimized to acceptable levels.

Stratification is a common feature of the command area soils, as described above young, stratified alluvial sediments with little structural development. This stratification has implication for irrigation management. The different soil layers or horizons have widely differing textures and therefore water holding capacities that tend to change abruptly rather than gradually. This could result in water passing quickly through the top soil which has, for instance, sandy loam or loamy sand textures and correspondingly low water holding capacities, and concentrating in a fine textured layer below the reach of the plant roots. This can cause also salt build up.

6.1.2 Effective Soil depth

The soil depth in the study area is dominantly very deep (>150 cm). Presence of rock fragments and weakly compacted layer limit the effective soil depth in the command area soils (Table 6.1). The deep augurings made to about 4.5 m depth at the bottom of the sampled profiles indicate that the materials limiting root depth (such as cemented carbonate and silica) are not encountered within the observed depth. At the time of surveying ground water table was not encountered within 4.5 m depth.

6.1.3 Drainage and Permeability

The overall drainage of the soils in the project area is well to excessively rapid. This is attributed to the dominance of medium to coarse soil texture.

6.1.4 Soil Structure and Compaction

Soils of the study area have dominantly sub angular blocky structure on the surface. The bulk density values of the soils range from 1.47 to 1.91 g cm⁻³. The bulk density of agricultural soils range from 1.1 to 1.4 g cm⁻³. Hence the bulk density values of most of the soils seem to have values above the acceptable range for agricultural soils. This might be attributed to presence of compacted layer and rock fragments. Thus, root development will be restricted by soil compaction in the 1C-HLV, 1SCL-FLCA, 1SL-FLCA, 1C-MVR, 1L-MFL, 1SiC-CLV, 1SL-HLV, 1SCL-MFL, 1SiC-VrLV, 1SiC-VrLV, 2L-VrLV, and 1SiC-VrLV mapping units. Therefore these mapping units require breaking of compacted layer during land preparation, i.e. before cotton planting, to enhance rooting depth.

In addition in these units farm operation during wet condition and uncontrolled field traffic will also cause soil compaction and thereby affect soil structure, air filled porosity, water infiltration and root development. Therefore, permanent traffic lanes should be considered essential in the command area to protect the productive areas of fields. Proper spacing of inter-rows and the use of low pressure high flotation tires on all axles should be considered as additional measures to reduce/prevent soil compaction.

According to Meyer (2011) details of measures to minimize damage by compaction are summarized as follows:

- Increase organic matter by trashing. Don't burn tops and trash. Plant legumes or cover crops before replanting.
- Work in poorly drained soils in the drier periods.
- Improve irrigation scheduling and ensure adequate drying off before harvesting.
- Improve farm planning and roads to reduce infield travel distances and improve surface water management.
- Keep tire surface contact pressure low. Use large, wide diameter, flexible carcass, low inflation pressure tires. Radial tires are better than cross-ply tires.
- Ensure that the total mass is distributed over all axles. Axle loads should not exceed 10 tonnes. Tandem axles with single wheels are better than single axles with dual wheels. On a single axle, duals are better than a single wheel. Walking beam axles reduce the compaction effect.
- Avoid using non-slewing loaders in wet conditions.
- Infield traffic should be restricted to widely spaced traffic paths, and confined to the inter-row.
- Reduce the number of passes by combining operations.
- Operate at maximum speed to keep the duration of pressure to a minimum.
- Use tracked vehicles on soils with a low bearing capacity to reduce sinkage and compaction.

6.1.5 Moisture Retention

The available water holding capacity (AWC) of the soils ranges from 42.6 to 188 mm/m within the top 100 cm layer on horizon basis. The wider range of AWC (low to high) in the study area is related to textural variation.

Table 6. 1: Morphological characteristics of the representative pedons of the soils

Table 6. 2: Physical characteristics of the representative pedons of the soils

6.1.6 Infiltration and Hydraulic Conductivity

The optimum infiltration rate of the soils in the project area ranges from 0.7 (suitable for surface irrigation) to 12.3 cm/hr (marginally suitable for surface irrigation; too rapid) in the top 30 cm. The average infiltration values of the soils indicate requirement of lining of canals either in the form of using geo membranes or hydro flumes for surface irrigation method. The hydraulic conductivity of the soils ranges from 0.06 to 0.7 m/day.

6.1.7 Flooding

Flooding is common in incidence in the Omo valley by Omo River and hence for the proposed irrigation development, flood control mechanism is mandatory in most part of the command area.

6.2 Soil Chemical Characteristics

Chemical characteristics of representative profiles are given in Table 6.2 and a guide for chemical data interpretation is given in Appendix table 1.

6.2.1 Soil Reaction

The pH values of the soil increase with soil depth and the values (including the deep auger samples) range from 6.33 to 8.33. The pH of the surface soils range from 6.3 to 7.2. The overall pH values of the soils indicate that the soils of the study area are slightly acid to neutral in the upper part and slightly alkaline to very strongly alkaline at depth.

Soil pH has a significant importance in soil-plant relationships because it determines the:

- Solubility and availability of plant nutrients
- Activity of roots of higher plants, and
- Activity of desirable soil microorganisms particularly the nitrogen fixers and nitrifiers whose activities are seriously depressed in strongly acid and strongly alkaline soils.

Generally, for agricultural purpose, soils with pH values within the range of 5.8 to 7.5 are suitable and more trouble free than those with higher or lower pH values.

In slightly to very strongly alkaline soils the levels of available Fe, Mn, Zn, Cu and Co are so low that plant growth is constrained. Phosphorous availability is likewise reduced in alkaline soil commonly to a deficiency level.

6.2.2 Cation Exchange Capacity

Cation exchange capacity (CEC) is a measure of the nutrient retention capacity of the soils and is an important index of soil fertility. The CEC of the surface soils range from 16.96 to 60.14 $\text{cmol}_c \text{ kg}^{-1}$ soil. The CEC values indicate that the nutrient retention capacity of the soils is medium to very high. The low CEC value is attributed to the low clay and organic matter content of the soils.

6.2.3 Base Saturation Percentage and Cationic Balance

Base saturation percentage (BSP) is a measure of the degree of saturation of the exchange complex (CEC) by the exchangeable basic cations (Ca, Mg, K and Na). It is often used as index of soil fertility. The BSP of the soils is very low to very high, ranging from 17 to 100%. In addition to BSP, relative proportion of the exchangeable cations is used as a measure of soil fertility (nutrient availability). Although most of the exchangeable Ca, Mg and K content of the soils are above the critical values this does not prove a balanced proportion of the exchangeable bases. Potassium uptake would be reduced as Ca and Mg are increased; conversely uptake of these two cations would be reduced as the available supply of K is increased (Havlin et al., 1999).

The ratio of exchangeable Ca to Mg in the surface soils range from 2.1 (low Ca) to 4.3 (very favorable for crop production). According to Landon (1991) likely inhibition of Ca uptake by the relatively higher amounts of Mg when the Ca/Mg ratio is <2.5, very favorable for crop production when the Ca/Mg ratio is between 2.5 to 6, and favorable for crop production when the Ca/Mg ratio is 6 to 12.

The ratio of the exchangeable Mg to K in the surface soils is between 3.04 (very favorable for crop production) and 23.4 (high Mg to prevent K uptake). According to Landon (1991) low Mg (when the Mg/K ratio is <2), very favorable (when the Mg/K ratio is 2 to 5), and favorable (when the Mg/K ratio is 5 to 15) proportion between the two exchangeable cations in the soils. However, the Mg/K ratio > 15 indicating high Mg likely to prevent K uptake.

Most soils have <2% K/CEC which implies below the minimum K level for topsoils. This implies the response of Cotton to K application is likely. Application of potash is usually done at the time of planting (basal application). This ensures a good establishment of the crop and a subsequent supply of potash throughout the whole crop cycle. However, as the soils in the command are dominantly medium to coarse textured, there is a likely loss of potash by leaching. Hence, it is recommended to split the dose in two (half dose as basal application and half dose as top dressing) to ensure a continuous supply of K to cotton crop.

6.2.4 Sodicity

Exchangeable Sodium Percentage (ESP) is the proportion of the exchange complex (CEC) occupied by the exchangeable Na and it is a measure of the deleterious effect of excess amount of Na mainly on the physical properties (soil moisture movement and aeration) of soils. An ESP values greater than 15% or exchangeable Na contents greater than 3 Cmolc kg⁻¹ soil are considered indicative of Na hazard and the soils are considered as sodic.

The ESP values of the soils in the project area generally increases with soil depth. However the values are less than 10 implying the soils are none sodic.

6.2.5 Electrical Conductivity

Electrical conductivity of the saturation extract (ECe) is a measure of soil salinity – an index of soil fertility. Soil salinity affects plant growth by inducing moisture stress due to osmotic pressure difference and causing nutrient imbalance due to the presence of excessive amounts of soluble salts. The ECe of the soils in the project area increases with soil depth. The ECe value of the soils (including the deep auger samples) is less than 2 dS m^{-1} . Soils with ECe less than 2 dS m^{-1} are considered non-saline and do not restrict growth and development of most sensitive crops.

6.2.6 Total Nitrogen and Organic Carbon Content

The total nitrogen (TN) content of the surface soils ranges from 0.014 to 0.21%. The overall TN content of the soils ranges from low to medium. According to Havlin et al. (1999), TN content of soils are categorized <0.15 as low, 0.15-0.25 as medium and >0.25 % as high. The organic carbon content of the surface soils ranges from 0.4 to 1.83 % (Very low).

6.2.7 Available Phosphorus

The available phosphorus (P) content of the soils in the study area decreases with soil depth and the values range from 12.72 to 27.32 mg/kg soils in the surface. This indicates that the P content of the surface soils is high.

6.2.8 Carbonates

Carbonates in soils affect both the physical (such as moisture retention) and chemical (pH and nutrient availability) properties of the soils. Some crops are sensitive to excessive amounts of carbonates in soils. The carbonate content of the soils in the study area range from 0.82 to 8.3%.

6.2.9 Available Micro Nutrients

The available Fe, Mn, Zn, Cu, and B content of the soils range from 6.68 to 85.35, 3.14 to 49.3, 0.75 to 31.57, 0.01 to 5.5, and 0.03 to 0.62 mg/kg soil respectively.

According to critical values of available micronutrients set by (Havlin et al 1999; Jones, 2003) the amount of Fe and Mn in the surface soils are adequate. As cotton requires 2960 g Fe to yield 2500 kg ha⁻¹ (Jones, 2003) the continuous production without replenishing these nutrients might hinder or reduce cotton production. The poor availability of zinc (< 1.00 mg/kg soil) and Cu (< 0.6 mg/kg soil) in the soils needs immediate intervention to sustain cotton production that requires 116 g of Zn and 120 g Cu (g ha⁻¹) to yield 2500 kg ha⁻¹.

Micronutrient status of the soils reveals that available B is below the critical limit and requires immediate attention as Cotton is highly responsive to B application.

Table 6. 3: Chemical characteristics of the representative pedons/auger observation points of the soils

Table 6. 4: Soil characteristic and respective recommendation of intervention

7. CONCLUSIONS AND RECOMMENDATIONS

The soil survey of the Omo Valley Farm Irrigation Project identified eighteen mapping units the basis of slope, surface soil texture, and major soil group. On the basis of morphological, physical and chemical characteristics five major soil groups were identified, namely Fluvisols, Cambisols, Luvisols, Vertisols and Arenosols.

The soils are very deep and the texture is dominantly sandy loam with slightly hard (dry) friable (moist) and non-sticky and non-plastic wet consistency and generally well to somewhat excessively drained with relatively high infiltration.

Most soils characterized by the presence of rock fragments though the degree of abundance, size and weathering stage varies. Mapping units 1SL-HFL, 2S-HAR, and 2SL-FLCA have abundant rock fragments within the top 100 cm depth. This layer together with dominant medium to coarse texture is responsible for water loss via seepage in furrows. These properties downgrade the suitability class of most soils of the project area for surface irrigation. In these soils land preparation should be performed with great care to avoid deep plowing so that more rock fragments from sub surface layers will not be brought to the surface and hamper Cotton cultivation. However, some soils depict compacted layer within the top 100 cm layer and hence require sub-soiling to break the compacted layer and these should be done with great care following the mapping unit/soil map of the command area.

Soils with high silt content in the surface have developed a surface crust/capping which inhibits infiltration and seed germination and increases run off. These soils require discing at regular intervals preferably before irrigation to promote infiltration. In addition, if these soils left dry for significant periods, then this increases soil loss through wind erosion and hence should not be left dry for long.

Crevassing is a common phenomenon in a stratified alluvial soil and hence the means to control this lie on not allowing water to enter the soil through cracks. Therefore prior to any development for irrigation the land must be leveled and present cracks filled in during land preparation and also the soils should be kept moist. Crevassing phenomenon can be minimized to acceptable levels but may not be fully overcome.

Stratification is a common feature of the command area soils. This stratification has implication for irrigation management. The different soil layers or horizons have widely differing textures and therefore water holding capacities that tend to change abruptly rather than gradually. This could result in water passing quickly through the coarse top soil and concentrating in a fine textured sub surface layer below the reach of the plant roots. This can cause also salt build up.

Soils of the study area are dominantly sub angular blocky on the surface. The bulk density values are higher than the acceptable range for agricultural soils and also imply there is compacted horizon within the soil solum.

The pH of the soils is slightly acid to neutral in the surface and slightly alkaline to very strongly alkaline in the subsurface horizons. The soils have medium to high cation exchange capacity-nutrient retention capacity and are dominantly low base saturated. There is no

balanced proportion of the basic cations in the soils. In some soils the content of Mg relative to Ca is high and may inhibit Ca availability to crops and the content of Mg relative to K is high and may inhibit K uptake by crops. Similarly, most soils exhibit $<2\%$ K/CEC which implies K is below the critical value for tropical soils and implies the response of Cotton to K application is likely. Application of K should be in a split (half dose as basal application and half dose as top dressing application) to avoid K leaching in medium to coarse textured soils and K fixation in fine textured soils which is typical feature of soils in the command area.

The electrical conductivity of saturated paste extract of most of the surface soils is less than 2dS/m with no subsurface salinity risk. The exchangeable sodium percentages (ESP) of the soils are generally increases with soil depth and the values are lower than 10% (on pedon basis) implying none-sodic.

The available phosphorus content of the soils is high. However, the total nitrogen and organic carbon content of the soils are very low implying the need for N fertilization and application of organic matter. Available Fe and Mn content might not be deficient for Cotton production. Available Zn, Cu and B of most soils is marginal to deficient for Cotton crop.

In slightly to very strongly alkaline soils the levels of available Fe, Mn, Zn, Cu and Co are so low that plant growth is constrained and also available P can be reduced to a deficiency level. Hence, monitoring and control of macro (P) and micronutrients (Fe, Cu, Zn, Mn) availability, especially Fe (as Cotton is high Fe demanding crop), salinity and sodicity hazard as well as effect of K and Fe-fertilization trials are recommended.

As the site is characterized by high soil pH coupled with relatively high air temperature due attention should be given during N containing fertilizer selection and method of application to avoid loss of N due to volatilization.

The soil profile depicts common biological activity-termite presence in the command area soils. Hence termite management activities, which include integrated pest management, are highly recommended.

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APPENDICES

Appendix 1: Guideline for soil data interpretation

Parameter	Range	Rating	Remark
pH _{H2O(1:2.5)}	<4.5	Extremely acid	Source: Jones, J. Benton, 2003- Agronomic handbook: management of crops, soils, and their fertility.
	4.5-5.0	Very strongly acid	
	5.1-5.5	Strongly acid	
	5.6-6.0	Moderately acid	
	6.0-6.5	Slightly acid	
	6.6-7.3	Neutral	
	7.4-8.0	Slightly alkaline	
	8.1-9.0	Strongly alkaline	
EC _e (dS/m)	>9.0	Very strongly alkaline	Source: Jones, J. Benton, 2003- Agronomic handbook: management of crops, soils, and their fertility.
	<2	None saline	
	2-4	Slightly Saline	
	4-8	Moderately saline	
	8-15	Strongly saline	
CEC (Cmol _c kg ⁻¹ soil)	>15	Very Strongly saline	Source: Jones, J. Benton, 2003- Agronomic handbook: management of crops, soils, and their fertility.
	>40	Very high	
	25-40	High	
	12-25	Medium	
	6-12	Low	
Base saturation (%)	<6	Very low	Source: Landon (1991)
	<20	Very low	
	21-40	low	
	41-60	Medium	
	61-80	High	
Exch. Ca (Cmol _c kg ⁻¹ soil)	81-100	Very high	Source: Landon (1991)
	>20	Very high	
	10-20	High	
	5-10	Medium	
	2-5	Low	
Exch. Mg (Cmol _c kg ⁻¹ soil)	<2	Very low	Source: Landon (1991)
	>8	Very high	
	3-8	High	
	1-3	Medium	
	0.3-1	Low	
Exch. K (Cmol _c kg ⁻¹ soil)	<0.3	Very low	Source: Landon (1991)
	>1.2	Very high	
	0.6-1.2	High	
	0.3-0.6	Medium	
	0.2-0.3	Low	
Exch. Na (Cmol _c kg ⁻¹ soil)	<0.2	Very low	Source: Landon (1991)
	>2.0	Very high	
	0.7-2.0	High	
	0.3-0.7	Medium	
	0.1-0.3	Low	
Organic carbon (%)	<0.1	Very low	Source: Landon (1991)
	>20	Very high	
	10-20	High	
	4-10	Medium	
	2-4	Low	
Total N (%)	<2	Very low	Source: Landon (1991)
	<0.15	Low	
	0.15-0.25	Medium	
Ca/Mg	>0.25	High	Source: Havlin et al. (1999) Kildehal Method
	>12	Very High	
	6-12	High	
	2.5-6	Medium	
	<2.5	Low	
			High Ca
			Favorable
			Very favorable
			Low Ca

Parameter	Range	Rating	Remark
Mg/K	>15	Very High	High Mg
	5-15	High	Favorable
	2-5	Medium	Very favorable
	<2	Low	Low Mg
Ca+Mg/K	>40	Very High	High Ca+Mg
	25-40	High	Favorable
	15-25	Medium	Very favorable
	<15	Low	Low Ca+Mg
K: CEC Ratio	2%	Minimum level	
ESP (%)	<15	Non-sodic	
	>15	Sodic	
Av. P (mg kg ⁻¹)	>12	High	Source: Havlin et al. (1999)
	8-11	Medium	Olsen-Extractable Available P
	4-7	Low	
	<4	Very Low	
CaCO ₃ (%)	<1	Low	
	1-4	Medium	
	4-10	High	
	>10	Very high	
Fe	>4.5	High (sufficient)	Source: Havlin et al. (1999)
	2.6 – 4.5	Marginal	DTPA-Extraction
	0-2.5	Low (Deficient)	
Mn	>1	High (sufficient)	
	-	Marginal	
	<	Low (Deficient)	
Zn	>1	High (sufficient)	
	0.6-1.0	Marginal	
	<0.5	Low (Deficient)	
Cu	>0.6	High (sufficient)	
	0.4-0.6	Marginal	
	<0.4	Low (Deficient)	
B	>2.0	High	
	0.5-2	Adequate	
	<0.5	Low (Deficient)	

According to Sims (2000), the range of critical values for optimum crop production for K, Ca and Mg are from 0.28 - 0.51, 1.25 - 2.5, and 0.25 - 0.5 cmol (+)/kg soil, respectively.

Effective Soil Depth: The depth of soil penetrable by roots without considering groundwater table and toxic substances

Depth Categories

- Very deep - >150 cm
- Deep - 100 – 150 cm
- Moderately deep - 50 – 100 cm
- Shallow - 30 – 50 cm
- Very shallow - < 30 cm

Drainage Class: Combination of internal and external drainage.

- Very poorly drained
- Poorly drained
- Imperfectly drained
- Moderately well drained
- Well drained
- Somewhat excessively drained
- Excessively drained

Basic Infiltration: Suitability for Surface Irrigation Rate (cm/h)

- <0.1 -Unsuitable (too slow) but suitable for rice
- 0.1 – 0.3 -Marginally suitable (too slow), marginally suitable for rice
- 0.3 – 0.7 -Suitable; unsuitable for rice
- 0.7 – 3.5 -Optimum
- 3.5 – 6.5 -Suitable
- 6.5 – 12.5 -Marginally suitable (too rapid); small basins needed
- 12.5 – 25.0 - Suitable only under special conditions, very small basins needed
- >25 - Unsuitable (too rapid) overhead irrigation methods only

Hydraulic Conductivity: Permeability is a General Term for the Same Ability to Transmit Water (FAO)

K(m/day): Hydraulic Conductivity Class

- <0.2 Very slow
- 0.2 – 0.5 Slow
- 0.5 – 1.4 Moderately slow
- 1.4 – 1.9 Moderately rapid
- 1.9 – 3 Rapid
- > 3 Very rapid

Available Water Holding Capacity

AWC mm/m: Rating for Irrigation Suitability

- Low - < 120
- Medium - 120 – 180
- High - > 180

According to Beernaert (1990), available water content values are rated < 8 as very low, 8 – 12 as low, 12 – 19 as medium, 19 – 21 as high and >21 V% as very high.

Soil Nutrient Classifications Interpretation

Very low to low	Very high probability of achieving a response to applied nutrient; unlikely probability of achieving a response to applied ameliorant for toxicity.
Moderately low	High probability of achieving a response to applied nutrient; possible or low probability of achieving a response to applied ameliorant for toxicity.
Marginal	Possible or low probability of achieving a response to applied nutrient; high probability of achieving a response to applied ameliorant for toxicity.
Adequate to high	Unlikely probability of achieving a response to applied nutrient; very high probability of achieving a response to applied ameliorant for toxicity.

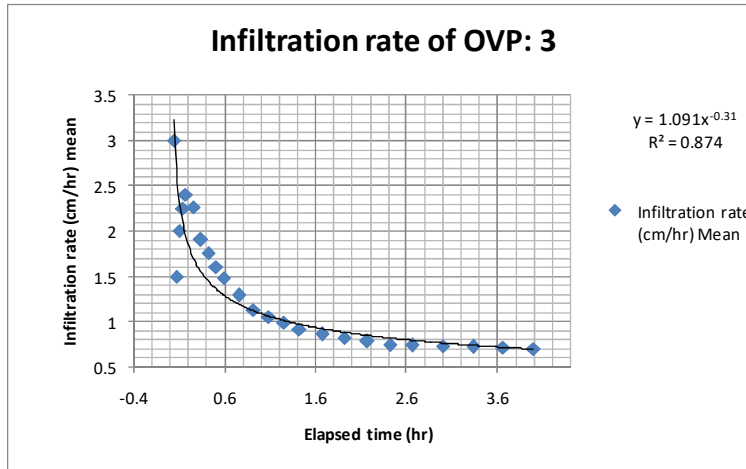
Source: Soil Analysis: An Interpretation Manual, 1999, CSIRO Publishing, Collingwood, Australia.

Soil Analysis Interpretation by Test Rating

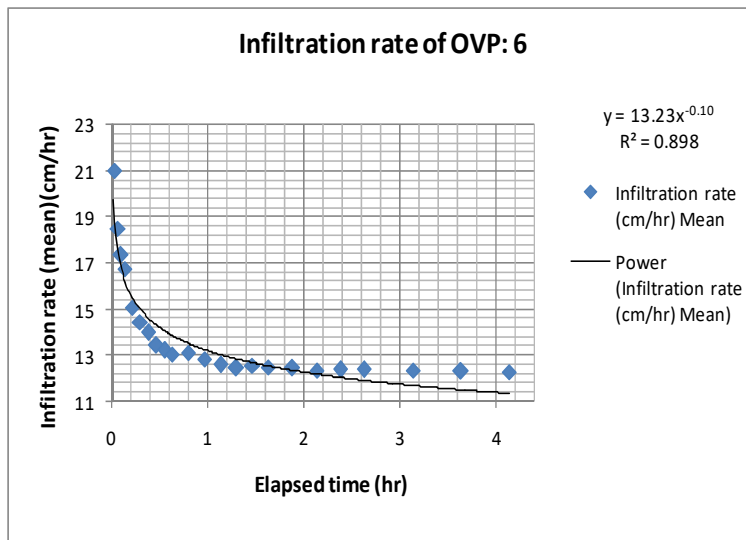
Rating	Interpretation
Low	Profitable response in almost all cases
Medium	Profitable response in most cases
High	Profitable response rare
Very High	Not Profitable to apply fertilizer
Excessive	Application may lower crop yield or quality

Source: Soil Fertility Handbook, 1998, Ontario Ministry of Agriculture, Canada.

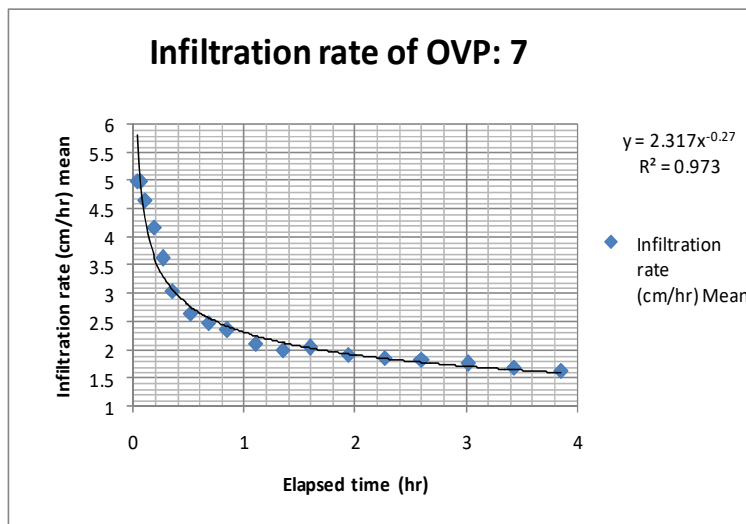
Representative soil infiltration rates



Infiltration rate of 1C-HLV



Infiltration rate of 1LS-HFL



Infiltration rate of 1C-MVR

Appendix 2: Profile Description

SOIL PROFILE DESCRIPTION

Profile code: OVP: 1 **Mapping unit:** 1SL-UFL
Status: Pit with sample
Soil classification (WRB, 2006): Umbric Fluvisols **Date:**
090115
Author: Zeinu and Eyoal **Coordinate:** Long.(N):
0579750
Land form: Level plain Lat.(E):
0192500
Slope class: Very gently **Elevation:**
404
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>280cm
Micro topography: None **Rock out crops:**
None
Parent material: Metamorphic / Quartzite **S. Coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Well drained **Surface sealing:**
Fine/slightly hard
Drainage external: Slow **Water table:**
Unknown
Land cover: Open shrubs land **Land use:**
Extensive
Erosion status: Sheet erosion with moderate degree & 10-25%
grazing/ Nomadism coverage

1A1:0-36cm: Dark Yellowish Brown (10YR 4/4 (dry), Dark brown(10YR3/6)(moist); clear and smooth boundary; Sandy loam; very few coarse sub angular freshly weathered Quartz; moderate coarse columnar structure; slightly hard (dry) friable(moist); none sticky none plastic(wet); very few coarse and very few fine roots; very few fine channels and common very fine interstitial pores; none calcareous.

2A2:36-96cm: Yellowish brown (10YR 5/4 (dry); Dark yellowish brown(10YR3/4)(moist); clear and smooth boundary; Sand; few medium sub angular freshly weathered Quartz rock fragments; single grain structure; loose (dry) & (moist) none sticky none plastic(wet); very few very fine and very few fine roots; few termite biological features; very few medium channels and common very fine interstitial pores; none calcareous.

3A3:96-110cm: Yellowish brown (10YR 5/6 (dry), Dark yellowish brown(10YR3/6)(moist); clear and smooth boundary; Silt loam; weak fine sub angular blocky structure; slightly hard (dry) & friable (moist) none sticky none plastic(wet); very few very fine and very few fine roots; very few coarse channels and common very fine interstitial pores; none calcareous.

4A3:110-176cm:Dark yellowish brown (10YR3/4(dry); Dark yellowish brown(10YR3/6)(moist); abrupt and smooth boundary; few fine distinct clear reddish brown mottles; Loamy sand; weak medium sub angular blocky structure; slightly hard (dry) & friable (moist); none sticky none plastic(wet); very few very fine roots; few termite biological features; very few coarse channels and few very fine interstitial pores; none calcareous.

5A4:176-200cm:Dark yellowish brown (10YR3/6(dry); Dark brown(10YR3/3)(moist); few very fine faint diffused reddish brown mottles; Clay; massive structure; very hard (dry) & very friable (moist); very sticky very plastic(wet); common termite biological features; few medium channels and few very fine interstitial pores; none calcareous.

200-250cm: Brown (7.5YR4/4)(Dry), Dark Brown(7.5YR3/4)(Moist); Clay; slightly hard(Dry) very friable(moist) very sticky very plastic(wet); none calcareous

250-280cm: Yellowish brown(10YR5/6)(Dry), Dark yellowish brown(10YR3/6)(Moist); Sand; loose(Dry) loose(moist); none sticky none plastic(wet); None calcareous.

Profile code: OVP:2 **Mapping unit:** 2LS-UFL **Status:** *Pit with sample*
Soil classification (WRB, 2006): Umbric Fluvisols *Fluvisols*
Date: 090115
Author: Zeinu and Eyoal **Coordinate:** Long(N):
0580500
Land form: Level plain Lat(E):
0193000
Slope class: Gently **Elevation:**
410
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: None **Rock out crops:**
None
Parent material: Metamorphic/ Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Somewhat excessively **Surface sealing:**
None
Drainage external: Slow **Water table :**
Unknown
Land cover: Open shrubs land & open wood **Land use:**
Extensive
Erosion status: Sheet erosion with slight degree & 5-10%
grazing/Nomadism
coverage

1A1:0-25cm: Yellowish Brown (10YR 5/6 (dry), Dark yellowish brown(10YR3/6)(moist); clear and smooth boundary; Loamy sandy; weak medium sub angular blocky structure; slightly hard (dry) very friable(moist); none sticky none plastic(wet); very few fine roots; few medium channels and very few fine interstitial pores; none calcareous.

2A2:25-77cm: Dark yellowish brown (10YR 4/6 (dry), Dark brown(10YR3/6)(moist); Abrupt and smooth boundary; Loamy sand; weak medium columnar structure; slightly hard (dry) & very friable; (moist) none sticky none plastic(wet); common very fine roots; very few fine channels and few very fine interstitial pores; none calcareous.

3A3:77-127cm: Dark yellowish brown (10YR 4/6 (dry); Dark brown(10YR3/6)(moist); Abrupt and smooth boundary; Sand; Single grain structure; loose (dry) & (moist); none sticky none plastic(wet); common very fine roots; few very fine interstitial pores; none calcareous.

4A4:127-135cm: Yellowish brown (10YR 5/4 (dry); Dark yellowish brown(10YR3/4)(moist); abrupt and smooth boundary; Sandy clay loam; weak medium sub angular blocky structure; slightly hard (dry) & friable (moist); slightly sticky & plastic(wet); very few fine channels and few very fine interstitial pores; none calcareous.

5A5:135-159CM:Yellowish brown (10YR 5/6 (dry), Dark yellowish brown(10YR3/6)(moist); Abrupt and smooth boundary; Sand; few fine flat freshly weathered Quartzite rock fragments single grain structure; loose (dry) & (moist); none sticky none plastic(wet); few termite biological features; very few medium channels and few very fine interstitial pores; none calcareous.

6A6:159-200cm:Yellowish brown (10YR 5/6 (dry), Dark yellowish brown(10YR3/6)(moist); Common medium distinct clear reddish brown mottle; Silty clay; weak coarse sub angular blocky structure; slightly hard (dry) very friable(moist); slightly sticky slightly plastic(wet); very few fine channels and few very fine interstitial pores; none calcareous.

Profile code: OVP:3 Mapping unit: 1C-HLV		Status: <i>Pit with sample</i>	
Soil classification (WRB, 2006): Haplic Luvisols 120115		Date:	
Author: 0581559	Zeinu and Eyoal	Coordinate:	Long(N):
Land form: 0196000	Level plain		Lat(E):
Slope class: 439	Nearly level	Elevation:	
Slope form:	straight	Map sheet No:	
Slope Position: >300cm	Lower slope	Depth to bedrock:	
Micro topography:	Termite mound/1.5/0.01% None	Rock out crops:	
Parent material: None	Metamorphic/ Quartzite	S.	coarse
Eff. soil depth: Medium /medium /very	Very deep	Surface	cracks:
Drainage class: Fine /slightly hard	Moderately drained	Surface	sealing:
Drainage external: Unknown	Slow	Water table :	
Land cover: Extensive	Open shrubs land & open wood	Land	use:
Erosion status:	Sheet and rill erosion with slightly degree & 5-10%, grazing/Nomadism 0-5% coverage consecutively active at present		
0-27cm:	Brown (7.5YR 4/3 (dry), Very dark brown(7.5YR2.5/3)(moist); Gradual and smooth boundary; Silty clay; Strong coarse sub angular blocky structure; very hard (dry) very firm(moist); very sticky very plastic(wet); very few fine and medium roots; very few very fine channels and common fine interstitial pores; none calcareous.		
27-60cm:	Dark Brown (7.5YR 3/3 (dry), Very dark brown (7.5YR2.5/2)(moist); clear and smooth boundary; Clay; moderate medium sub angular blocky structure; very hard (dry) firm(moist); very sticky & very plastic(wet); very few faint silken side discontinuous and irregular horizontal pedface coating; continuous platy clay with moderately cemented; very few very fine roots; few very fine interstitial pores; none calcareous.		
60-100cm:	Brown(7.5YR 4/4 (dry), Very dark brown(7.5YR2.5/2)(moist); diffuse and smooth boundary; Clay; weak medium sub angular blocky structure; hard (dry) friable(moist); very sticky & very plastic(wet); Common soft concretion medium irregular soft calcium carbonate with white color; very few very fine roots; very few fine channels & common very fine interstitial pores; moderately calcareous.		
100-150cm:	Very dark brown (10YR 3/2 (dry), Very dark grayish brown(10YR2/2)(moist); clear and smooth boundary; Clay; weak coarse granular blocky structure; hard (dry) friable(moist); very sticky & very plastic(wet); few faint silken side discontinuous and irregular horizontal pedface coating; many soft concretion medium irregular soft calcium carbonate with white color; few termite biological features;		

very few medium channels & few very fine interstitial pores; moderately calcareous.

150-200cm: Very dark brown (10YR 3/2 (dry), Black(10YR2/1)(moist); Clay; Massive structure; hard (dry) friable to firm(moist); very sticky & very plastic(wet); very faint silken side discontinuous and irregular horizontal pedface coating; continuous platy clay and calcium carbonate with moderately cemented; common soft concretion medium Irregular soft calcium carbonate with white color; few termite biological features; very few very fine interstitial pores; slight calcareous.

200-300cm: Very dark brown (10YR 3/2 (dry), Black(10YR2/1)(moist); Clay; very hard (dry) friable to firm (moist); very sticky very plastic(wet); continuous platy clay and calcium carbonate with moderate cementation; common soft concretion medium irregular soft calcium carbonate with white color; slightly calcareous.

Remark: because of cementation the depth is limited at 300cm
Up to 100cm fine cracks are observed

Profile code: OVP:4 **Mapping unit:** 1SCL-FLCA **Status:** Pit with sample
Soil classification (WRB, 2006): Fluvisols **Date:** 130115
Author: Zeinu and Eyoal **Coordinate:** Long(N):
0580619
Land form: Level plain Lat(E):
0196402
Slope class: Very gently **Elevation:**
448
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200cm
Micro topography: Animal track with 0.5% **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Moderately drained **Surface sealing:**
Coarse /slightly hard
Drainage external: Slow **Water table:**
Unknown
Land cover: Open shrubs land & open wood **Land use:**
Extensive
Erosion status: Sheet and rill erosion with slight degree & 10-25%,
grazing/Nomadism
0-5% coverage consecutively active at present

0-34cm: Brown (7.5YR 4/4 (dry), Dark brown(7.5YR3/3)(moist); Abrupt and wavy boundary; Silty clay; Strong coarse sub angular blocky structure; hard (dry) friable to firm(moist); sticky & plastic(wet); very few coarse & very few very fine roots; very few fine channels and many very fine interstitial pores; none calcareous.

34-44cm: Yellowish brown(10YR 5/8 (dry), Dark yellowish brown(10YR3/6)(moist); Abrupt and wavy boundary; silt; single grain structure; loose (dry) & (moist); none sticky & none plastic(wet); few very fine roots; very few termite biological features; very few fine channels & common very fine interstitial pores; none calcareous.

44-100cm: Dark brown (7.5YR 3/3 (dry), Very dark brown(7.5YR2.5/3)(moist); Gradual and smooth boundary; Clay; moderate coarse sub angular blocky structure; hard (dry) friable to firm(moist); sticky & plastic(wet); continuous platy clay moderately cemented very few segregation and nodules; few fine rounded soft Manganese and black; very few very fine roots; few termite biological features; very few fine channels & few very fine interstitial pores; slightly calcareous.

100-150cm: Brown (7.5YR 4/6 (dry), Very dark brown(7.5YR3/4)(moist); Silty clay; very few fine and medium sub rounded freshly weathered quartzite rock fragment; moderate coarse sub angular blocky structure; slightly hard (dry) friable (moist); sticky & plastic(wet); very few fine channels & common very fine interstitial pores; slightly calcareous.

150-200: Dark brown (7.5YR 4/4 (dry), Very dark brown(7.5YR3/4)(moist); Loamy sand; common fine and medium sub rounded freshly weathered

quartzite rock fragment; weak coarse sub angular blocky structure; slightly hard (dry) friable (moist); none sticky & none plastic(wet); few soft concretion fine irregular soft calcium carbonate white; few termite biological features; few medium channels & common fine interstitial pores; slightly calcareous.

Remark: because of fine layer from 34-44cm is not sampled

Profile code: OVP: 5 **Mapping unit:** 1SL-FLCA **Status:** Pit with sample
Soil classification (WRB, 2006): Fluvisols **Date:** 130115
Author: Zeinu and Eyoal **Coordinate:** Long(N):
0580500
Land form: Level plain Lat(E):
0197500
Slope class: Gently **Elevation:**
457
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200cm
Micro topography: Termites mound/0.5-1m/0.1% **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:** None
Drainage class: Well drained **Surface sealing:** None
Drainage external: Slow **Water table:** Unknown
Land cover: Open shrubs land & open wood **Land use:**
Extensive
Erosion status: Sheet and rill erosion with slight degree & 10-25%,
grazing/Nomadism
0-5% coverage consecutively active at present

1A1:0-25cm: Brown (7.5YR 4/4 (dry) Dark brown(7.5YR3/3)(moist); Clear and smooth boundary; loamy sand; moderate medium sub angular blocky structure; slightly hard (dry) friable (moist); none sticky & none plastic(wet); fine & coarse very few roots; very few medium channels and many very fine interstitial pores; none calcareous.

25-100cm: Dark brown (7.5YR 3/4 (dry), Very dark brown(7.5YR2.5/2)(moist); Gradual and smooth boundary; Sandy clay loam; strong coarse sub angular blocky structure; very hard (dry) friable (moist); slightly sticky & slightly plastic(wet); continuous platy clay; sand and calcium carbonate moderately cemented; common soft concretion flat irregular soft white calcium carbonate; few very fine roots; common termite biological features; very few medium to coarse channels and few very fine interstitial pores; none calcareous.

100-165cm: Brown (7.5YR 4/4 (dry), Dark brown (7.5YR 3/4)(moist); Gradual and smooth boundary; Sandy clay loam; moderate medium sub angular blocky structure; slightly hard (dry) friable (moist); slightly sticky & slightly plastic(wet); very few segregation fine irregular soft white calcium carbonate; few termite biological features; very few fine channels & common very fine interstitial pores; slightly calcareous.

165-200cm: Yellowish red (5YR5/6 (dry), Dark reddish brown(5YR3/4)(moist); Loamy sand; very few fine flat freshly weathered quartzite rock fragment; massive structure; hard (dry) friable (moist); none sticky & none plastic(wet); continuous platy calcium carbonate and sand moderately cemented; very few segregated fine irregular soft white calcium carbonate; very few fine channels & very few very fine interstitial pores; slightly calcareous.

Remark: High cementation and fine crack at second layer observed

Profile code: OVP: 6 **Mapping unit:** 1SL-HFL **Status:** **Pit with sample**
Soil classification (WRB, 2006): Haplic Fluvisols **Date:** 170115
Author: Dawit and Abebayehu **Coordinate:** Long(N):
0576541
Land form: Level plain Lat(E):
0195924
Slope class: Gently **Elevation:**
418
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>310cm
Micro topography: Termites mound/3-4m/1% **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Well drained **Surface sealing:**
None
Drainage external: Well **Water table:**
Unknown
Land cover: Open shrubs land **Land use:**
Extensive
Erosion status: Sheet erosion with slight degree & 0-5% coverage
grazing/Nomadism

0-24cm: Brown (7.5YR 5/2 (dry), Brown(7.5YR74/2)(moist); Clear and smooth boundary; loamy sand; moderate medium sub angular blocky structure; slightly hard (dry) friable (moist); none sticky & none plastic(wet); few coarse many fine roots; common termite biological features; common medium interstitial pores; none calcareous.

24-72cm: Dark brown (7.5YR 3/3 (dry), Dark brown(7.5YR3/2)(moist); clear and smooth boundary; Sandy loam; common fine rounded and few medium subrounded weathered quartzite rock fragment; weak medium sub angular blocky structure; slightly hard (dry) friable (moist); none sticky & none plastic(wet); few fine roots; few termite biological features; very few fine channels and few fine interstitial pores; none calcareous.

72-110cm: Brown (7.5YR 4/3 (dry), Brown(7.5YR4/2)(moist); diffuse and smooth boundary; Loamy sand, abundant fine rounded and many medium sub rounded weathered quartzite rock fragment; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); none calcareous.

110-158cm: Dark brown(7.5YR 5/4 (dry), Brown(7.5YR3/3)(moist); clear and smooth boundary; Sand; many fine rounded and common medium sub rounded weathered quartzite rock fragment; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); few soft concretion fine rounded soft and hard white calciumcarbonate; moderately calcareous.

- 158-200cm: Brown(7.5YR 5/3 (dry), Brown(7.5YR4/3)(moist); fine sand; many fine rounded and few medium sub rounded weathered quartzite rock fragment; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); slightly calcareous.
- 200-260cm: Brown (7.5YR 5/3 (dry), Brown(7.5YR4/3)(moist); Sand; abundant fine sub rounded and many medium rounded weathered quartzite rock fragment; loose (dry) loose (moist); none sticky & none plastic(wet); none calcareous.
- 260-310cm: Brown (7.5YR 5/2 (dry), Brown(7.5YR4/3)(moist); Loamy sand; abundant fine rounded and many medium sub rounded weathered quartzite rock fragment; loose (dry) loose (moist); none sticky & none plastic(wet); none calcareous.

Remark: Because of loose texture the depth is limited at 310cm

Profile code: OVP:7 **Mapping unit:** 1C-MVR **Status:** Pit with sample
Soil classification (WRB, 2006): Mollic Vertisols **Date:** 140115
Author: Tilahun & Danial **Coordinate:** Long(N):
0576854
Land form: Level plain Lat(E):
0192079
Slope class: Very gently **Elevation:**
385
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>450cm
Micro topography: None **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Moderately drained **Surface sealing:**
None
Drainage external: Slow **Water table:**
Unknown
Land cover: Open shrubs land **Land use:**
Extensive
Erosion status: None
grazing/Nomadism/Selective

tree felling

- 0-30cm: Brown (7.5YR 4/4 (dry), Dark brown(7.5YR73/4)(moist); Clear and smooth boundary; Silty clay; moderate medium sub angular blocky structure; hard (dry) friable (moist); very sticky & plastic(wet); common medium & fine roots; common medium channels pores; none calcareous.
- 30-90cm: Dark brown (7.5YR 3/3 (dry), Dark brown(7.5YR3/2)(moist); clear and smooth boundary; Clay; strong coarse sub angular blocky structure; very hard (dry) firm (moist); very sticky & very plastic(wet); common prominent continuous clay pedface; continuous platy clay compacted but not cemented; few fine rounded hard black manganese; common fine roots; common termites biological features; few medium channels pores; none calcareous.
- 90-150cm: Dark brown (7.5YR 3/4 (dry), Dark brown(7.5YR3/3)(moist); clear and smooth boundary; Clay; strong medium angular & sub angular blocky structure; hard (dry) friable (moist); very sticky & very plastic(wet); few distinct discontinuous and irregular clay vertical pedface; common fine rounded hard black manganese; few fine roots; common termites biological features; few medium channels pores; none calcareous.
- 150-185cm: Brown(7.5YR 5/3 (dry), Dark brown(7.5YR3/3)(moist); clear and smooth boundary; Sandy loam; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); few fine roots; common termites biological features; very few fine channels pores, none calcareous.
- 185-200cm: Brown(7.5YR 4/4 (dry), Dark brown(7.5YR3/3)(moist); Loamy sand; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); few fine interstitial pores, none calcareous.

- 200-240cm: Dark yellowish brown(10YR 4/4 (dry), Dark yellowish brown(10YR3/4)(moist); Sandy loam; loose (dry) loose (moist), none sticky & none plastic(wet), none calcareous.
- 240-280cm: Brown(10YR 5/3 (dry),Dark Brown(10YR3/3)(moist); Silty clay; slightly hard (dry) very friable (moist); sticky & plastic(wet); none calcareous.
- 280-340cm: Dark yellowish brown(10YR 4/6 (dry),Dark yellowish brown(10YR3/6)(moist); Fine sand; loose (dry) loose (moist); none sticky & none plastic(wet); none calcareous.
- 340-450cm: Pale brown(10YR 6/3 (dry),Dark Brown(10YR3/3)(moist); Silt clay; slightly hard (dry) very friable (moist); sticky & plastic(wet); none calcareous.

Remark: Fine crack 0 up 90cm are observed with 1cm width

Profile code:	<i>OVP: 8</i>	Mapping unit:	<i>1L-MFL</i>	Status:	<i>Pit with sample</i>		
Soil classification (WRB, 2006):	<i>Mollic Fluvisols</i>			Date:	<i>130115</i>		
Author:	<i>Tilahun & Danial</i>	Coordinate:	<i>Long(N):</i>				
<i>0576400</i>							
Land form:	<i>Level plain</i>		<i>Lat(E):</i>				
<i>0194000</i>							
Slope class:	<i>Very gently</i>		Elevation:				
<i>402</i>							
Slope form:	<i>straight</i>		Map sheet No:				
Slope Position:	<i>Lower slope</i>		Depth to bedrock:				
<i>>200m</i>							
Micro topography:	<i>None</i>		Rock out crops:				
<i>None</i>							
Parent material:	<i>Metamorphic/Quartzite</i>		S. coarse				
<i>None</i>							
Eff. soil depth:	<i>Very deep</i>		Surface cracks:				
<i>Medium/medium/</i>							
Drainage class:	<i>Moderately drained</i>		Surface sealing:				
<i>Fine /slightly hard</i>							
Drainage external:	<i>Slow</i>		Water table:				
<i>Unknown</i>							
Land cover:	<i>Open grass land</i>		Land use:				
<i>Extensive</i>							
Erosion status:	<i>Sheet and rill erosion with slight degree & 0-5% grazing/Nomadism/Selective</i>						
	<i>Coverage</i>	<i>active</i>	<i>at</i>	<i>present</i>			
	<i>tree felling</i>						
0-20cm:	Brown (7.5YR 4/3 (dry), Dark brown (7.5YR73/3)(moist); Clear and smooth boundary; Silt clay; moderate fine sub angular blocky structure; hard (dry) very friable (moist); sticky & plastic(wet); few medium & abundant fine roots, few fine interstitial pores; none calcareous.						
20-70cm:	Dark brown (7.5YR 3/3 (dry), Very dark brown(7.5YR2.5/2)(moist); clear and smooth boundary; Clay; strong coarse sub angular blocky structure, very hard (dry) friable (moist); very sticky & very plastic(wet); few faint discontinuous and irregular clay horizontal pedface; continuous platy compacted but not cemented clay; few fine rounded hard black manganese; common fine roots; termites biological features; few medium channels pores; none calcareous.						
70-110cm:	Dark brown (7.5YR 3/4 (dry), Very dark brown(7.5YR2.5/3)(moist); clear and smooth boundary; Clay; medium fine to medium angular & sub angular blocky structure; very hard (dry) friable to firm (moist); very sticky & very plastic(wet); few fine roots; few termites biological features; few fine pores, none calcareous.						
110-150cm:	Strong brown (7.5YR 4/6 (dry), Dark brown (7.5YR3/4)(moist); clear and smooth boundary; Loamy sand; weak fine sub angular blocky structure; slightly hard (dry) very friable (moist); none sticky & none plastic(wet); few very fine roots; few termites biological features; very few fine channels pores; none calcareous.						
150-170cm:	Brown(7.5YR 4/3 (dry), Dark brown(7.5YR3/3)(moist); Clear and smooth; Sandy loam; moderate medium structure; hard (dry) very friable (moist); none sticky & none plastic(wet); strongly calcareous.						

170-175cm: Dark yellowish brown (10YR 4/6 (dry); Dark yellowish brown(10YR3/6)(moist); Clear and smooth; Loamy sand; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); none calcareous.

175-200cm: Brown(7.5YR 4/4 (dry), Dark brown(7.5YR3/3)(moist); Few fine distinct diffuse reddish brown mottle; Silty clay loam; moderate medium sub angular blocky structure; slightly hard (dry) friable (moist); sticky & plastic(wet); none calcareous.

Remark: b/n 170-175 thin layer

Profile code: OVP: 9 **Mapping unit:** 1SiC-CLVm **Status:** Pit without sample
Soil classification (WRB,20006): Cutanic Luvisols (manganiferic)
Date: 140115
Author: Tilahun & Danial **Coordinate:** Long(N):
0578970
Land form: Level plain Lat(E):
0191500
Slope class: Gently **Elevation:**
390
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: None **Rock out crops:**
None
Parent material: Metamorphic/ quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Moderately drained **Surface sealing:**
Fine /slightly hard
Drainage external: Slow **Water table:**
Unknown
Land cover: Open grass land **Land use:**
Extensive
Erosion status: None
grazing/Nomadism/Selective tree felling

0-20cm: Dark Yellowish Brown (10YR 4/4 (dry), Dark Yellowish Brown (10YR73/4)(moist); Clear and smooth boundary; Silt clay; weak fine sub angular blocky structure; slightly hard (dry) very friable (moist); very sticky & plastic(wet); few medium & many fine roots; common termites biological features; common medium channels pores; none calcareous.

20-60cm: Dark brown (10YR 3/3 (dry), Dark Yellowish Brown (10YR73/4)(moist); Clear and smooth boundary; Clay; Strong medium sub angular blocky structure; hard (dry) friable (moist); very sticky & very plastic(wet); few faint discontinuous and irregular pedface clay coating; continuous pisolithic compacted but not cemented clay and manganese cementation; common fine rounded black hard manganese nodules; few medium & fine roots; common termites biological features; common medium channels pores; none calcareous.

60-110cm: Dark Yellowish Brown (10YR 3/4 (dry), Dark Brown (10YR3/3)(moist); Clear and smooth boundary; Clay; moderate coarse sub angular blocky structure; very hard (dry) friable (moist); very sticky & very plastic(wet); few faint discontinuous and irregular pedface clay coating; continuous pisolithic compacted but not cemented clay and manganese cementation; many fine rounded black hard manganese nodules; few fine roots; few termites biological features; very few fine channels pores; none calcareous.

110-160cm: Dark Yellowish Brown (10YR 3/4 (dry), Dark Brown (10YR3/3)(moist); Gradual and smooth boundary; Clay; few medium and fine sub rounded weathered quartz rock fragments; moderate coarse sub angular blocky structure; very hard (dry) friable (moist); very sticky & very plastic(wet); few fine rounded black hard manganese nodules; very few fine roots; none calcareous.

160-200cm: Dark Yellowish Brown (10YR 4/4 (dry), Dark Yellowish Brown (10YR73/4)(moist); Silt clay; few fine Sub rounded weathered quartz rock; moderate fine sub angular blocky structure; slightly hard (dry) very friable (moist); sticky & plastic(wet); none calcareous.

Profile code: OVP:10 **Mapping unit:** 2S-HFL **Status:** Pit with sample
Soil classification (WRB, 2006): Haplic Fluvisols **Date:**
150115
Author: Dawit and fikadu **Coordinate:** Long(N):
0578500
Land form: Level plain Lat(E):
0196850
Slope class: Nearly level **Elevation:**
443
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: Termites mound/1-1.5m/1% **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
Few fine
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Well drained **Surface sealing:**
None
Drainage external: Well **Water table:**
Unknown
Land cover: Open shrubs land **Land use:**
Extensive
Erosion status: Sheet erosion with slight degree & 0-5% coverage
grazing/Nomadism/and active at present

0-30cm: Dark Yellowish Brown (7.5YR 5/2 (dry), Dark Yellowish Brown (7.5YR4/1)(moist); Diffuse and smooth boundary; Loamy sand; few fine sub rounded weathered quartz rock; weak medium sub angular blocky structure; loose (dry) loose (moist); none sticky & none plastic(wet); few coarse & common fine roots; few termites biological features; few fine interstitial pores; none calcareous.

30-90cm: Brown (7.5YR 5/3 (dry), Brown (7.5YR4/3)(moist); Clear and smooth boundary; Sand; common sub rounded and few fine rounded weathered quartz rock; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); few fine roots; common termites biological features; common medium interstitial pores; none calcareous.

90-155cm: Brown (10YR 4/2 (dry), Dark brown (10YR3/2)(moist); Clear and smooth boundary; Sandy clay loam; strong medium sub angular blocky structure; slightly hard (dry) friable to firm (moist); sticky & plastic(wet); common medium irregular hard and soft white calcium carbonate; very few coarse and few fine roots; moderately calcareous.

155-200cm: Brown (10YR 4/3 (dry), Dark Brown (10YR3/3)(moist); Sandy clay; moderate medium sub angular blocky structure; slightly hard (dry) friable to firm (moist); sticky & plastic(wet); common fine rounded hard and soft white calcium carbonate; strongly calcareous.

Profile code: OVP:11 **Mapping unit:** 1SL-HLVds **Status:** *Pit with sample*
Soil classification (WRB, 2006): Haplic Luvisols (Dystric, Siltic)
Date: 150115
Author: Tilahun **Coordinate:** Long(N):
0579500
Land form: Level plain Lat(E):
0193500
Slope class: Nearly level **Elevation:**
404
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: None **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
Few fine
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Moderately drained **Surface sealing:**
Fine /slightly hard
Drainage external: Slow **Water table :**
Unknown
Land cover: Open grass land **Land use:**
Extensive grazing & settl.
Erosion status: Sheet erosion with moderate degree & 5-10%% coverage and
active at present
0-20cm: Brown (7.5YR 4/4 (dry), Dark brown (7.5YR3/4)(moist); Clear and
smooth boundary; Silty clay loam; weak medium sub angular blocky
structure; slightly hard (dry) very friable (moist); slightly sticky &
slightly plastic(wet); few fine rounded black soft and hard manganese;
few medium & common fine roots; common termites biological
features; common fine channels pores; none calcareous.
20-70cm: Dark brown (7.5YR 3/4 (dry), Dark brown (7.5YR3/3)(moist); Clear and
smooth boundary; Clay; strong coarse sub angular blocky
structure; hard (dry) firm (moist); very sticky & very plastic(wet); few
fine discontinuous and irregular horizontal pedface clay coating;
continuous platy compacted but not cemented clay cemen common
fine rounded black soft and hard manganese; common fine roots;
common termites biological features; common fine channels pores;
none calcareous.
70-110cm: Strong brown(7.5YR 4/6 (dry), Dark brown (7.5YR3/4)(moist); Clear
and smooth boundary; Loamy sand; few medium flat freshly
weathered quartzes rock; weak medium sub angular blocky structure;
slightly hard (dry) very friable (moist); none sticky & none plastic(wet);
very few fine roots; few termite biological features; common fine
channels; none calcareous.
110-150cm: Brown (7.5YR 5/4 (dry), Brown (7.5YR4/4)(moist); Clear and smooth
boundary; Loamy sand; few medium flat freshly weathered quartzes
rock; weak medium sub angular blocky structure; slightly hard (dry)
very friable (moist); none sticky & none plastic(wet); very few fine
roots; few termite biological features; common fine channels; none
calcareous.

150-200cm: Brown (7.5YR 4/4 (dry), Dark brown (7.5YR3/3)(moist); Silty clay; moderate medium sub angular blocky structure; slightly hard (dry) friable (moist); sticky & plastic(wet); many fine flat reddish brown soft Iron; none calcareous.

Profile code: OVP:12 **Mapping unit:** 1SCL-MFL **Status:** Pit with sample
Soil classification (WRB, 2006): Mollic Fluvisols **Date:** 150115
Author: Tilahun and Danial **Coordinate:** Long(N):
0579470
Land form: Level plain Lat(E):
0194451
Slope class: Very gently **Elevation:**
419
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: Termites mound/0.5m/1% **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
Few fine
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Moderately drained **Surface sealing:**
Fine /slightly hard
Drainage external: Slow **Water table :**
Unknown
Land cover: Open grass land **Land use:**
Extensive
Erosion status: Sheet erosion with moderate degree & 5-10%%
grazing/Nomadism/settle
Coverage and active at present
ment/selective felling

0-25cm: Brown (7.5YR 4/3 (dry), Dark brown (7.5YR3/3) (moist); Clear and smooth boundary; Silty clay; weak coarse sub angular blocky structure; hard (dry) very friable (moist); sticky & plastic(wet); many fine & common medium roots; common termites biological features; few fine channels pores; none calcareous.

25-40cm: Strong brown (7.5YR 4/6 (dry), Dark brown (7.5YR3/4)(moist); Clear and smooth boundary; Loamy sand; weak fine sub angular blocky structure; slightly hard (dry) very friable (moist); none sticky & none plastic(wet); common fine & few medium roots; few termites biological features; few fine channels pores; none calcareous.

40-90cm: Dark brown (7.5YR 3/3 (dry), Dark brown (7.5YR3/2)(moist); Clear and smooth boundary; Silty clay; moderate medium platy structure; slightly hard (dry) very friable (moist); sticky & plastic(wet); few fine & very few medium roots; common termites biological features; common fine channels pores; none calcareous.

90-120cm: Dark brown (7.5YR 3/4 (dry), Dark brown (7.5YR3/2)(moist); Clear and smooth boundary; Clay; moderate fine sub angular blocky structure; hard (dry) friable (moist); very sticky & very plastic(wet); continuous platy compacted but not cemented clay cementation; very few fine; few termites biological features; few fine channels pores; none calcareous.

120-160cm: Dark brown (7.5YR 3/3 (dry), Dark brown (7.5YR3/2)(moist); Clear and smooth; Sandy clay; moderate medium sub angular blocky structure; hard (dry) very friable (moist); sticky & slightly plastic(wet); very few fine roots; few fine channels pores; none calcareous;

160-200cm: Dark brown (7.5YR 3/4 (dry), Dark brown (7.5YR3/3)(moist); Sandy loam; moderate fine sub angular blocky structure; slightly hard (dry) very friable (moist); none sticky & none plastic(wet); none calcareous.

Profile code:	<i>OVP: 13</i>	Mapping unit:	<i>2SL-HFL</i>	Status:	<i>Pit without sample</i>		
Soil classification (WRB, 2006):	<i>Haplic Fluvisols</i>				Date: <i>170115</i>		
Author:	<i>Tilahun and Danial</i>	Coordinate:	<i>Long</i>	<i>(N):</i>			
<i>0580500</i>							
Land form:	<i>Level plain</i>		<i>Lat</i>	<i>(E):</i>			
<i>0195300</i>							
Slope class:	<i>Nearly level</i>		Elevation:				
<i>444</i>							
Slope form:	<i>Concave</i>		Map sheet No:				
Slope Position:	<i>Upper slop</i>		Depth to bedrock:				
<i>>200m</i>							
Micro topography:	<i>Termites mound/0.5-1m/1%</i>		Rock out crops:				
<i>None</i>							
Parent material:	<i>Metamorphic/Quartzite</i>		S.	coarse			
<i>None</i>							
Eff. soil depth:	<i>Very deep</i>		Surface	cracks:			
<i>None</i>							
Drainage class:	<i>Well drained</i>		Surface	sealing:			
<i>None</i>							
Drainage external:	<i>Well</i>		Water	table:			
<i>Unknown</i>							
Land cover:	<i>Open wood, shrubs and bush land</i>		Land	use:			
<i>Extensive</i>							
Erosion status:	<i>Sheet erosion with moderate degree & 5-10%% grazing/Nomadism/settle</i>						
	<i>Coverage and active at present</i>						
	<i>ment/selective felling</i>						
0-30cm:	Dark grayish brown (10YR 4/2 (dry), Dark yellowish brown (10YR3/4)(moist); Clear and smooth boundary; Loamy sand; weak medium sub angular blocky structure; slightly hard (dry) very friable (moist); none sticky & none plastic(wet); common fine and few medium roots; common fine channels pores; none calcareous.						
30-80cm:	Brown (7.5YR 4/2 (dry), Dark brown (7.5YR3/2)(moist); Clear and smooth boundary; Loamy sand; weak medium sub angular blocky structure; slightly hard (dry) very friable (moist); none sticky & none plastic(wet); common fine and very few medium roots; few burrow biological features; few fine channels pores; none calcareous.						
80-135cm:	Dark brown (7.5YR3/3)(moist); Clear and smooth boundary; Medium sand; single grain structure; loose (moist); none sticky & none plastic(wet); very few very fine roots; very few fine channels pores; none calcareous.						
135-170cm:	Dark brown (7.5YR3/4)(moist); Diffuse and smooth boundary; Medium sand; single grain blocky structure; loose (moist); none sticky & none plastic(wet); very few very fine roots; very few fine channels pores; none calcareous.						
170-200cm:	Strong brown (7.5YR5/6)(moist); Coarse sand; common fine & few medium rounded freshly weathered quartzes rock; single grain structure; loose (moist); none sticky & none plastic(wet); none calcareous.						

Profile code: OVP:14 **Mapping unit:** 1SL-HFLd **Status:** Pit with sample
Soil classification (WRB, 20006): Haplic Fluvisols(Dystric) **Date:** 150115
Author: Zeinu and Eyoal **Coordinate:** Long(N):
0582060
Land form: Level plain Lat(E):
0191640
Slope class: Nearly level **Elevation:**
394
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: None **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Well drained **Surface sealing:**
None
Drainage external: Slow **Water table :**
Unknown
Land cover: Open shrubs land & open wood **Land use:**
Extensive
Erosion status: Sheet erosion with slight degree & 5-10%
grazing/Nomadism
coverage & active at present

1A1:0-25cm: Dark yellowish brown (10YR 4/6 (dry), Dark yellowish brown(10YR3/6)(moist); Clear and smooth boundary; Loamy sandy; very few very fine faint diffused grayish mottle; weak coarse columnar structure; slightly hard (dry) very friable(moist) none sticky none plastic(wet); very few very fine and very few medium roots; few termites biological features; common fine channels and very few very fine interstitial pores, none calcareous.

2A2:25-45/53cm: Dark yellowish brown (10YR 4/4 (dry), Dark yellowish brown(10YR3/4)(moist); Abrupt and wavy boundary; Sandy; very few very fine faint diffused grayish mottle; common fine sub round freshly weathered quartzes rock; weak medium columnar structure; slightly hard (dry) very friable(moist); none sticky none plastic(wet); very few very fine and very few medium roots; few very fine channels and common very fine interstitial pores, none calcareous.

3A3:45/53-62cm: Yellowish brown (10YR 5/6 (dry), Dark yellowish brown(10YR3/6)(moist); Abrupt and smooth boundary; Silt; few fine distinct clear reddish brown mottle; weak coarse sub angular blocky structure; slightly hard (dry) very friable(moist); none sticky none plastic(wet); very few very fine roots; very few fine channels and common very fine interstitial pores, none calcareous.

4A4:62-105cm: Yellowish brown (10YR 5/4 (dry), Dark yellowish brown(10YR3/4)(moist); Abrupt and smooth boundary; Loamy sand; many medium prominent clear grayish mottle; weak medium sub angular blocky structure; slightly hard (dry) very friable(moist); none sticky none plastic(wet); very few very fine roots; few termite biological features; very few fine channels and common very fine interstitial pores, none calcareous.

- 5A5:105-140cm: Strong brown (7.5YR 4/6 (dry), Very dark brown(7.5YR2.5/3)(moist); Abrupt and smooth boundary; Silt clay; moderate coarse sub angular blocky structure; slightly hard (dry) very friable(moist); sticky and plastic(wet); very few very fine & very few fine roots; few termite biological features; few medium channels and common very fine interstitial pores; none calcareous.
- 6A6:140-150cm:Strong brown (7.5YR 4/6 (dry), Dark brown(7.5YR3/3)(moist); Abrupt and smooth boundary; Silt; weak coarse sub angular blocky structure; slightly hard (dry) very friable(moist); none sticky none plastic(wet); few very fine roots; very few fine channels and common very fine interstitial pores, none calcareous
- 7A7:150-200cm:Dark brown (7.5YR 3/4 (dry), Very dark brown(7.5YR2.5/3)(moist); Clay; moderate coarse sub angular blocky structure; slightly hard (dry) friable(moist); very sticky and very plastic(wet); few very fine roots; very few fine channels and common very fine interstitial pores; none calcareous

Profile code: OVP:15 **Mapping unit:** 1CL-HFLs **Status:** Pit with sample
Soil classification (WRB, 2006): Haplic Fluvisols(Siltic) **Date:** 160115
Author: Zeinu and Eyoal **Coordinate:** Long(N):
0575400
Land form: Level plain Lat(E):
0194000
Slope class: Nearly level **Elevation:**
401
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200cm
Micro topography: None **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
Wide /deep /very widely
Drainage class: Moderately drained **Surface sealing:**
Thick/ slight hard
Drainage external: Slow **Water table :**
Unknown
Land cover: Intensively cultivated land **Land use:**
Fallow system cultivation
Erosion status: Sheet erosion with slight degree 5-10% coverage
active at present

1A1: 0-25cm: Brown (10YR 4/3 (dry), Dark yellowish brown (10YR3/4)(moist); Clear and smooth boundary; Clay; weak medium granular structure; hard (dry) friable to firm(moist); sticky plastic(wet); very few fine and few coarse roots; very few fine channels and many very fine interstitial pores, none calcareous.

1A2: 25-75cm: Brown (7.5YR 4/4 (dry), Dark brown (7.5YR3/3)(moist); Clear and smooth boundary; Clay; strong coarse sub angular blocky structure; hard (dry) friable to firm(moist); very sticky & very plastic(wet); very few faint discontinuous and irregular silken side pedface coating; very few very fine and very few coarse roots; very few fine channels and common very fine interstitial pores, none calcareous.

2A3:75-100cm: Yellowish brown (10YR 5/4 (dry), Dark brown (10YR3/3)(moist); Clear and smooth boundary; Silt clay; massive structure; slightly hard (dry) soft (moist); sticky & slightly plastic (wet); very few very fine roots; very few very fine channels and few very fine interstitial pores; moderately calcareous.

3A4:100-145cm:Light yellowish brown (10YR 6/4 (dry), Dark yellowish brown (10YR3/4)(moist); Gradual and smooth boundary; Silt clay; weak medium sub angular structure; hard (dry) friable to firm (moist); sticky & plastic(wet); few medium flat white hard and soft calcium carbonate nodules; very few very fine roots; few fine channels and common very fine interstitial pores; slightly calcareous.

4A5:145-180cm:Yellowish brown (10YR 5/4 (dry), Dark yellowish brown(10YR3/4)(moist); Clear and smooth Boundary; Siltyclayloam; few fine prominent clear reddish brown mottle; massive structure;

loose (dry) soft (moist); slightly sticky & slightly plastic(wet); very few very fine roots; few very fine interstitial pores; moderately calcareous.

5A6:180-200cm: Yellowish brown (10YR 5/6 (dry), Dark yellowish brown(10YR3/6)(moist); Silt; few fine faint diffused reddish brown mottle; weak medium platy structure; slightly hard (dry) very friable (moist); none sticky & none plastic(wet); few very fine interstitial pores; slightly calcareous.

Remark: On the last layer few and fine crushed snail shells observed

Profile code: OVP: 16 **Mapping unit:** 2S-ARd **Status:** Pit with sample
Soil classification (WRB, 2006): Haplic Arenosols (Dystric) **Date:** 150115
Author: Dawit and fikadu **Coordinate:** Long(N):
0578800
Land form: Level plain Lat(E):
0198000
Slope class: Nearly level **Elevation:**
483
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: Termites mound/1-1.5m/1% **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
Few fine & medium
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Well drained **Surface sealing:**
None
Drainage external: Well **Water table :**
Unknown
Land cover: Open shrubs land **Land use:**
Extensive
Erosion status: Sheet erosion with slight degree & 0-5% coverage
grazing/Nomadism/ and active at present

0-25cm: Brown (7.5YR 5/3 (dry), Brown (7.5YR4/2)(moist); Clear and smooth boundary; Loamy sand; common fine sub rounded & common medium rounded weathered quartz rock; weak fine sub angular blocky structure; loose (dry) loose (moist); none sticky & none plastic(wet); few medium & common fine roots; common termites biological features; common medium interstitial pores; none calcareous.

25-130cm: Brown (7.5YR 4/3 (dry), Dark brown (7.5YR3/3)(moist); Clear and smooth boundary; Coarse sand; abundant medium sub rounded and many fine rounded weathered quartz rock; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); very few fine roots; very few termites biological features; few fine interstitial pores; none calcareous.

130-200cm: Brown (7.5YR 4/4 (dry), Brown (7.5YR4/2)(moist); fine sand; few coarse & common fine sub rounded weathered quartz rock; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); none calcareous.

Profile code: OVP: 17 **Mapping unit:** 1SL-HFL **Status:** Pit without sample
Soil classification (WRB, 2006): Haplic Fluvisols **Date:** 150115
Author: Zeinu and Eyoal **Coordinate:** Long (N):
0581944
Land form: Level plain Lat (E):
0192509
Slope class: Nearly level **Elevation:**
407
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: None **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Well drained **Surface sealing:**
Fine/ slightly hard
Drainage external: Slow **Water table :**
Unknown
Land cover: Open shrubs land **Land use:**
Extensive
Erosion status: Sheet & Rill erosion with moderate degree 5-10%
grazing/Nomadism & 0-5% coverage consecutively & active at present

0-25cm: Yellowish brown (10YR 5/6 (dry), Dark yellowish brown(10YR3/6)(moist); Clear and smooth boundary; Sand; weak coarse platy structure; slightly hard (dry) very friable(moist) none sticky none plastic(wet); few termite biological features; very few fine channels and many very fine interstitial pores, none calcareous.

25-40cm: Yellowish brown (10YR 5/4 (dry), Dark yellowish brown(10YR4/4)(moist); Clear and smooth boundary; Sand; very few fine sub rounded freshly weathered quartz rock; weak coarse platy structure; slightly hard (dry) very friable(moist); none sticky none plastic(wet); very few very fine roots; very few fine channels and common very fine interstitial pores, none calcareous.

40-64cm: Yellowish brown (10YR 5/4 (dry), Dark yellowish brown(10YR4/4)(moist); Clear and smooth boundary; common medium prominent clear grayish mottle; few medium sub rounded freshly weathered quartz rock; weak coarse columnar structure; slightly hard (dry) very friable(moist); none sticky none plastic(wet); very few coarse roots; very few termite biological features; very few fine channels and common fine interstitial pores, none calcareous.

64-100cm: Dark Yellowish Brown (10YR 5/6 (dry), Dark yellowish brown(10YR3/6)(moist); Clear and smooth boundary; common medium distinct clear black mottle; Loamy sand; few medium sub rounded weathered quartz rock; weak medium columnar structure; slightly hard (dry) very friable(moist); none sticky none plastic(wet); very few coarse roots; very few fine channels and common fine interstitial pores, none calcareous.

- 100-125cm: Dark Yellowish Brown (10YR 4/6 (dry), Dark yellowish brown(10YR3/6)(moist); Clear and smooth boundary; common medium prominent clear reddish brown mottle; Silty loam; moderate coarse sub angular blocky structure; slightly hard (dry) very friable(moist); slightly sticky& slightly plastic(wet); very few coarse roots; very few fine channels and common very fine fine interstitial pores, none calcareous.
- 125-200cm: Yellowish brown (10YR 5/4 (dry), Dark yellowish brown(10YR3/4)(moist); Common medium prominent clear grayish mottle; Sand; few coarse sub rounded & common medium flat freshly weathered quartz rock; single grain structure; loose (dry) loose (moist); none sticky none plastic(wet); very few coarse roots; very few fine channels and common fine interstitial pores, none calcareous.

Profile code: OVP: 18 **Mapping unit:** 1SiC-VrLVm **Status:** Pit without sample
Soil classification (WRB, 2006): Vertic Luvisols (Manganiferri) **Date:** 160115
Author: Tilahun & Danial **Coordinate:** Long (N):
0578100
Land form: Level plain Lat (E):
0192500
Slope class: Very gently **Elevation:**
398
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: Termites mound/0.5-2.5m/1% **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
Medium/medium/wide
Drainage class: Moderately drained **Surface sealing:**
Fine /slightly hard
Drainage external: Slow **Water table:**
Unknown
Land cover: Open shrubs land **Land use:**
Extensive
Erosion status: Sheet erosion with slightly degree, 0-5% coverage
grazing/Nomadism/Selective Active at present tree felling

0-20cm: Brown (7.5YR 4/3 (dry), Dark Brown (10YR73/3)(moist); Clear and smooth boundary; Siltyclay; moderate medium sub angular blocky structure; slightly hard (dry) friable (moist); sticky & plastic(wet); common medium & few coarse roots; few termites biological features; few fine channels pores; none calcareous.

20-70cm: Dark Brown (7.5YR 3/3 (dry), Dark Brown (10YR73/2)(moist); Clear and smooth boundary; Clay; Strong coarse angular blocky structure; very hard (dry) very friable (moist); very sticky & very plastic(wet); few faint discontinuous and irregular clay pedface coating; continuous platy compacted but not cemented clay compaction; few fine sub rounded black hard manganese nodules; few medium & common fine roots; common open large borrow biological features; common fine channels pores; none calcareous.

70-120cm: Brown (7.5YR 4/4 (dry), Dark Brown (7.5YR3/4)(moist); Clear and smooth boundary; Loamy sand; weak fine sub angular blocky structure; slightly hard (dry) very friable (moist); none sticky & none plastic(wet); few fine roots; few termites biological features; few fine channels pores; none calcareous.

120-155cm: Dark Brown(7.5YR 3/4 (dry), Dark Brown (10YR73/3)(moist); Clear and smooth boundary; Siltyclay; weak medium platy structure; slightly hard (dry) friable (moist); sticky & plastic(wet); few fine flat black soft Manganese nodules; very few very fine roots; few termites biological features; few fine channels pores; slightly calcareous.

155-200cm: Brown (7.5YR 5/4 (dry), Brown (7.5YR4/3)(moist); Loamy sand; Common medium and few coarse rounded freshly weathered quartz rock; weak medium sub angular blocky structure; slightly hard (dry) very friable (moist); none sticky & none plastic(wet); very few very fine roots; none calcareous.

Remark: from 0 up to 20cm about 1cm width crack are observed

Profile code: OVP: 19 **Mapping unit:** 1SiC-VrLV **Status:** Pit with sample
Soil classification (WRB, 2006): Vertic Luvisols **Date:** 160115
Author: Zeinu and Eyoal **Coordinate:** Long (N):
0575600
Land form: Level plain Lat (E):
0192500
Slope class: Nearly level **Elevation:**
392
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200cm
Micro topography: None **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
Wide /deep /very widely
Drainage class: Moderately drained **Surface sealing:**
medium /slight hard
Drainage external: Slow **Water table:**
Unknown
Land cover: Intensively cultivated land **Land use:**
Irrigated agriculture, Fallow
Erosion status: Sheet erosion with slight degree 10-25% coverage system
cultivation active at present

0-30cm: Brown (7.5YR 4/4 (dry), Dark brown (7.5YR3/4)(moist); Clear and smooth boundary; Silty clay; Moderate coarse sub angular structure; slightly hard (dry) friable (moist); sticky & plastic(wet); very few very fine and few medium roots; many very fine interstitial pores, none calcareous.

30-80cm: Brown (7.5YR 4/4 (dry), Dark brown(7.5YR3/3)(moist); Clear and smooth boundary; Clay; strong coarse sub angular blocky structure; very hard (dry) firm(moist); very sticky & very plastic(wet); Continuous platy clay compaction with moderate degree; very few very fine and few coarse roots; very few fine channels and common very fine interstitial pores; none calcareous.

80-120cm: Brown (10YR 5/3 (dry), Dark brown(10YR3/3)(moist); Clear and smooth boundary; Few fine distinct reddish brown clear mottle; Clay; weak coarse granular structure; slightly hard (dry) friable (moist); sticky & plastic(wet); few fine sub rounded white soft calcium carbonate nodules; very few very fine & very few coarse roots; very few fine channels and many very fine interstitial pores; moderately calcareous.

120-162cm: Light yellowish brown (10YR 6/4 (dry), Dark yellowish brown (10YR3/6)(moist); Gradual and smooth boundary; common medium diffused clear yellowish brown mottle; Silty clay; weak medium sub angular blocky structure; slightly hard (dry) friable (moist); slightly sticky & slightly plastic(wet); very few very fine roots; few fine channels and common very fine interstitial pores; none calcareous.

162-200cm: Yellowish brown (10YR 5/4 (dry), Dark Yellowish Brown (10YR4/4)(moist); Many medium Prominent clear reddish brown mottle; Silty clay; strong medium platy structure; slightly hard(dry) friable (moist); slightly sticky & slightly plastic(wet); common medium freshly weathered black soft and hard manganese nodules; very few fine channels and few very fine interstitial pores; none calcareous.

Remark: from 0-80cm depth down the profile of pit fine cracks are observed

Profile code: OVP: 20 **Mapping unit:** 2SL-FLCAe

Status: *Pit with sample*
Soil classification (WRB, 20006): Fluvisols (Eutric) **Date:** 200115
Author: *Dawit and fasil* **Coordinate:** Long (N):
0577500
Land form: *Level plain* Lat (E):
0196750
Slope class: *Very gently* **Elevation:**
441
Slope form: *Complex* **Map sheet No:**
Slope Position: *Lower slope* **Depth to bedrock:**
>200m
Micro topography: *Termite mound/0.8-1.5m/1%* **Rock out crops:**
None
Parent material: *Metamorphic/Quartzite* **S. coarse**
None
Eff. soil depth: *Very deep* **Surface cracks:**
None
Drainage class: *Well drained* **Surface sealing:**
None
Drainage external: *Well* **Water table:**
Unknown
Land cover: *Open shrubs land & shrubs land* **Land use:**
Extensive
Erosion status: *Sheet erosion with moderate degree & 5-10% grazing/Nomadism/ Coverage and active at present*

0-25cm: Dark grayish brown(10YR 4/2 (dry), Dark Brown (10YR3/3)(moist); clear and smooth boundary; Sandy loam; common fine rounded and few medium sub rounded weathered quartz rock; moderate medium Sub angular blocky structure; slightly hard (dry) very friable (moist); slightly sticky & slightly plastic(wet); few medium & common fine roots; common termites biological features; common fine channels & common medium interstitial pores; none calcareous.

25-66cm: Brown (10YR 4/3 (dry), Dark grayish brown(10YR4/2)(moist); Clear and smooth boundary; Sandy clay loam; few fine sub rounded weathered quartz rock; weak coarse sub angular blocky structure; slightly hard (dry) friable (moist); sticky & plastic(wet); very few fine & few fine roots; few termites biological features; few very fine channels and few fine interstitial pores; slightly calcareous.

66-124cm: Yellowish brown (10YR 5/4 (dry), Brown (10YR4/3)(moist); diffused and smooth boundary; Coarse sand; abundant fine sub rounded and common coarse rounded weathered quartz rock; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); common fine irregular hard and soft white calcium carbonate nodules; strongly calcareous.

124-155cm: Grayish brown(10YR 5/2 (dry), Dark grayish brown(10YR4/2)(moist); diffused and smooth boundary; Sandy loam; few fine sub rounded and few medium rounded weathered quartz rock; moderate medium sub angular blocky structure; loose (dry) loose (moist); none sticky & none

plastic(wet); few fine irregular hard and soft white calcium carbonate concretion; moderately calcareous.

155-200cm: Light brownish gray (10YR 6/2 (dry), Grayish brown(10YR5/2)(moist); Sandy; few medium Sub rounded and many fine rounded weathered quartz rock; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); none calcareous.

Profile code: OVP: 21 **Mapping unit:** 1SL-FLCA **Status:** Pit with sample
Soil classification (WRB, 2006): Fluvisols Cambisols **Date:** 160115
Author: Dawite and **Coordinate:** Long(N):
0577600
Land form: Level plain Lat(E):
0194000
Slope class: Nearly level **Elevation:**
405
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: Termites mound/2-4m/3% **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Well drained **Surface sealing:**
None
Drainage external: Slow **Water table :**
Unknown
Land cover: Open shrubs land **Land use:**
Extensive
Erosion status: Sheet erosion with slight degree 0-5% coverage
grazing/Nomadism/ active at present

0-20cm: Brown(7.5YR 5/3 (dry), Dark grayish brown (10YR4/2)(moist); clear and smooth boundary; Loamysand; few fine sub rounded weathered quartz rock; weak medium subangular blocky structure; loose (dry) loose (moist); none sticky & none plastic(wet); few medium & many fine roots; common termites biological features; very few very fine channels & common fine interstitial pores; none calcareous.

20-67cm: Brown(7.5YR 4/3 (dry), Dark brown (7.5YR3/3)(moist); clear and smooth boundary; Sandyloam; very few medium rounded weathered quartz rock; moderate medium subangular blocky structure; slightly hard (dry) friable (moist); slightly sticky & slightly plastic(wet); few fine roots; few termites biological features; few medium interstitial pores; none calcareous.

67-115cm: Brown(7.5YR 4/4 (dry), Dark brown (10YR3/2)(moist); diffuse and smooth boundary; Loamysand; few medium rounded & common fine subrounded weathered quartz rock; weak fine subangular blocky structure; loose (dry) loose (moist); none sticky & none plastic(wet); few fine channels & very few very fine interstitial pores; none calcareous.

115-170cm: Brown(7.5YR 5/3 (dry), Brown (10YR4/3)(moist); Diffuse and smooth boundary; Sand; very few medium sub rounded weathered quartz rock; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); none calcareous.

170-200cm: Grayish brown (7.5YR 5/2 (dry), Dark grayish brown(10YR4/2)(moist); fine sand; very few coarse subrounded weathered quartz rock; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); none calcareous.

Profile code: OVP: 22 **Mapping unit:** 2L-VrLvm **Status:** Pit with sample
Soil classification (WRB, 2006): Vertic Luvisols (Manganiferic) **Date:** 170115
Author: Tilahun & Danial **Coordinate:** Long(N):
0580000
Land form: Level plain Lat(E):
0191500
Slope class: Very gently **Elevation:**
403
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: Hummocks/0.5m/0.5% coverage **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Moderately drained **Surface sealing:**
Fine /slightly hard
Drainage external: Slow **Water table:**
Unknown
Land cover: Open bush land and wood land **Land use:**
Extensive
Erosion status: Sheet & rill erosion with moderate degree 5-10%
grazing/Nomadism/Settle coverage active at present ments

0-20cm: Brown (7.5YR 4/3 (dry), Dark Brown (10YR7/3)(moist); Clear and smooth boundry; Siltyclay; moderate fine subangular blocky structure; hard (dry) very friable (moist); sticky & plastic(wet); common fine roots; open large burrow biological features; few medium channels and few fine interstitial pores; none calcareous.

20-65cm: Brown (7.5YR 4/4 (dry), Dark Brown (7.5YR3/4)(moist); Clear and smooth boundry; Siltyclay; moderate coarse platy structure; hard (dry) friable (moist); sticky & plastic(wet); few fine roots; few open large borrow biological features; common medium channels and few fine interstitial pores; none calcareous.

65-120cm: Strong brown (7.5YR 4/6 (dry), Dark Brown (7.5YR3/4)(moist); Clear and smooth boundry; Clay; strong coarse sub angular blocky structure; hard (dry) friable to firm (moist); very sticky & very plastic(wet); contineous platy compacted but not cemented clay cementation; very few fine flat black soft manganese concretion; very few fine roots; common open large borrow and few termites biological features; common medium channels and few fine interstitial pores; none calcareous.

120-160cm: Brown(7.5YR 4/4 (dry), Dark Brown (10YR3/3)(moist); Clear and smooth boundary; Siltyclay; moderate medium platy sructure; slightly hard (dry) very friable (moist); sticky & plastic(wet); common medium flat black soft Manganese concretions; very few very fine roots; few open large burrow biological features; few medium channels pores; none calcareous.

160-200cm: Strong brown (7.5YR 5/6 (dry), Strong brown (7.5YR4/6)(moist); Sandy clay; Common medium rounded freshly weathered quarze rock; weak fine subangular blocky structure; slightly hard (dry) very friable (moist); sticky & plastic(wet); none calcareous.

Remark: from 0 up to 20cm about less than 1cm width crack are observed

Profile code: OVP: 23 **Mapping unit:** 1SiC-VrLV **Status:** Pit without sample
Soil classification (WRB, 2006): Vertic Luvisols **Date:** 170115
Author: Zeinu and Eyoal **Coordinate:** Long(N):
0577132
Land form: Level plain Lat(E):
0195044
Slope class: Very gently **Elevation:**
411
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: None **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S.coarse**
None
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Well drained **Surface sealing:**
Fine /slightly hard
Drainage external: Slow **Water table:**
Unknown
Land cover: Open shrubs land **Land use:**
Extensive
Erosion status: Sheet erosion with moderate degree 10-25%
grazing/Nomadism coverage active at present

0-30cm: Dark yellowish brown (10YR 4/6 (dry), Dark yellowish brown(10YR3/6)(moist); Clear and smooth boundry; Siltyclay; strong medium sub angular blocky structure; hard (dry) friable(moist) sticky & plastic(wet); few very fine roots; few fine channels and many very fine interstitial pores, none calcareous.

30-66cm: Yellowish brown (10YR 5/6 (dry), Dark yellowish brown(10YR3/6)(moist); Clear and smooth boundry; few medium distinct greyish clear mottle; Siltyclay; moderate coarse angular sub angular blocky structure; slightly hard (dry) friable(moist) sticky & plastic(wet); few very fine roots; very few fine channels and many very fine interstitial pores, none calcareous.

66-125cm: Dark brown(7.5YR 3/3 (dry), Very dark brown(7.5YR2.5/3)(moist); Clear and smooth boundry; Clay; moderate coarse sub angular blocky structure; very hard (dry) firm (moist) very sticky & very plastic(wet); contineous platy moderate clay compaction; few very fine roots; very few fine channels and few very fine interstitial pores; slightly calcareous.

125-170cm: Brown(7.5YR 4/4 (dry), Dark brown(7.5YR3/3)(moist); Clear and smooth boundry; few fine distinct diffused brown mottle; Clay; few fine and very few medium sub rounded freshly weathered quartz; weak medium sub angular blocky structure; hard (dry) friable to firm (moist) sticky plastic(wet); few fine irregular white soft and hard calcium carbonate ccretion; few fine channels and common very fine interstitial pores; moderatly calcareous.

- 170-180cm: Strong brown(7.5YR 5/6 (dry), Dark brown(7.5YR3/4)(moist); Clear and smooth boundry; Sand; common fine and common medium sub rounded freshly weathered quarze; single grain structure; loose (dry) loose (moist) none sticky & none plastic(wet); common fine interstitial pores; none calcareous.
- 180-200cm: Yellowish brown(10YR 5/6 (dry), Dark yellowish brown(7.5YR3/6)(moist); common fine faint diffused redish brown mottle; Loamy sand; very few fine sub rounded weathered quarze; weak fine sub angular blocky structure; slightly hard (dry) very friable (moist) none sticky & none plastic(wet); very fine channels and common fine interstitial pores; none calcareous.

Remark: 0 up to 80cm fine crack are observed on the profile of the pit

Profile code: OVP: 24 **Mapping unit:** 1SL-HFL **Status:** Pit without sample
Soil classification (WRB, 2006): Haplic Fluvisols **Date:** 210115
Author: Dawite and fasile **Coordinate:** Long(N):
0578250
Land form: Level plain Lat(E):
0193600
Slope class: Level **Elevation:**
403
Slope form: straight **Map sheet No:**
Slope Position: Lower slope **Depth to bedrock:**
>200m
Micro topography: Termites mound/3-4m/1% **Rock out crops:**
None
Parent material: Metamorphic/Quartzite **S. coarse**
Few / medium
Eff. soil depth: Very deep **Surface cracks:**
None
Drainage class: Moderately drained **Surface sealing:**
None
Drainage external: Slow **Water table:**
Unknown
Land cover: Open shrubs land **Land use:**
Extensive
Erosion status: Sheet erosion with slightly degree 0-5% coverage
grazing/Nomadism/ active at present

0-23cm: Brown(7.5YR 5/3 (dry), Dark grayish brown (10YR4/2)(moist); clear and smooth boundry; Sandy loam; very few fine rounded weathered quartz rock; moderate medium subangular blocky structure; soft (dry) very friable (moist); slightly sticky & slightly plastic(wet); common fine and few medium roots; common termites biological features; few fine channels & common medium interstitial pores; none calcareous.

23-70cm: Brown(7.5YR 4/3 (dry), Dark brown (7.5YR3/2)(moist); clear and smooth boundry; Sandyclayloam; strong coarse sub angular blocky structure; hard (dry) friable to firm (moist); sticky & plastic(wet); few fine roots; common termites biological features; common fine channels and common medium interstitial pores; none calcareous.

70-104/108cm: Brown(7.5YR 5/3 (dry), Brown (10YR5/2)(moist); clear and wavy boundry; Sandy loam; moderate medium subangular blocky structure; soft (dry) very friable (moist); slightly sticky & slightly plastic(wet); none calcareous.

104/108-148cm: Brown(7.5YR 4/4 (dry), Brown (7.5YR4/3)(moist); Diffuse and smooth; Sandyclayloam; moderate fine sub angular blocky structure; slightly hard (dry) friable (moist); sticky & plastic(wet); none calcareous.

148-200cm: Brown (7.5YR 5/3 (dry), Dark grayish brown(10YR4/2)(moist); Fine sand; common fine rounded and few medium subrounded weathered quarze rock; single grain structure; loose (dry) loose (moist); none sticky & none plastic(wet); none calcareous.

Appendix 3: In-Situ Soil Physical Test

Appendix 4: Auger Data