

Technical Paper No. 76

SOILS OF KULUMSA AGRICULTURAL RESEARCH CENTER

**The Federal Democratic Republic of Ethiopia
Ethiopian Agricultural Research Organization**



**National Soil Research Center (NSRC)
Soil Survey and Land Evaluation Section**

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FOREWORD

One of the major achievements as a result of the recent restructuring of the national agricultural research system and the establishment of the Ethiopian Agricultural Research Organization (EARO) is the upgrading of the soil and water research to a program level and appointment of a Director of the Program.

One of the four major soil and water research programs under the Directorate is Soil and Water Resources Characterization and Evaluation Program, which is coordinated and largely implemented by the National Soil Research Center (NSRC). The main activity under this program is being soil survey and land evaluation.

In the past, lack of information on the type and characteristics of soils, even at research centers and benchmark locations, has been a serious drawback, not only for proper implementation of the soil and water research activities, but also for reliable interpretation and extrapolation of the overall agricultural research findings.

With the realization of the seriousness of this problem, the soil survey and land evaluation unit recently established under the NSRC, formulated a research/activity project for surveying the soils of all research centers in the shortest time possible, with the limited facilities and manpower available. As per the priorities set at program level in consultation with the Director of the SWRP, the survey activity started in 2000 research season for Kulumsa Agricultural Research Center.

The report is a standard soil survey report with a soil map at a scale of 1:5,000, showing the different soil units at the center. The survey report is an invaluable information for all researchers, which may help for identification and defining of appropriate research sites for proper interpretation and extrapolation of research results to similar areas.

If the necessary budgetary, facility and manpower requirements are fulfilled, I believe that each and every agricultural research center will have a similar report within the coming few years.

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1. INTRODUCTION

Ethiopia is an agrarian society whereby the livelihood of more than 85% of its population is based on subsistence farming. Agriculture has the greatest share of the country's economy as well as foreign earnings. On the other hand, climatic imbalance, poor farming practices and low level of inputs have forced the country to remain food deficient.

Research and extension in the agricultural sector has began long a go aiming at assisting farmers to improve their standard of living through increased agricultural productivity. So far, quite a number of research findings addressing major agricultural problems have been released for wider application. Some of the research findings, if not all, have proved to be more or less successful. However, there were also pitfalls here and there due to very generalized and approximation of recommendation. Amongst is dissemination of research outputs to areas not similar to where the research has been carried out due to lack of sufficient soils information for extrapolation of findings.

As regards to soil studies, a number of surveys have been carried out for different purposes at different times by different institutions. These surveys cover a sizeable are of the country. However, the scale and purpose of the studies allow only planning for development undertakings. A very detailed survey is necessary to characterize soils at research centers for the proper understanding of the research media and reliable extrapolation of research outcome.

At present there are more than 37 Agricultural Research Centers and Sub-centers in the country. Except for very few of them, mapping and characterization of soils at research centers and benchmark sites have not been done. This has made characterization of research conditions and identification of similar areas for extrapolation and dissemination of research outcomes difficult, if not impossible. Therefore, this study was undertaken for detail characterization of the soils at Kulumsa Research Center to generate the necessary soils information to be used by all the researchers.

2. DESCRIPTION OF THE AREA

2.1 Location and Access

Kulumsa Agricultural Research Center (KARC) is located in Oromia National Regional State, Arsi Administrative Zone. It is at about 170 Km south of Addis Ababa. Its geographical extent is from 8°00' to 8° 02' northern latitude and from 39° 07' to 39° 10' eastern longitude.

The Addis Ababa - Assela all-weather road provides the primary access to the area. The road letting to the farm bifurcates from this main road at about 7 Km before reaching the Assela town. Within the research farm, lanes between blocks provide the major access. The layout consists two units (the main farm and Ashal meda) and 48 blocks.

2.2 Climate

There is a first class met-station within the center that measures different climatic elements. According to the records from 1979 to 1999 (Annex 1), the mean annual rainfall is 788 mm. It has a uni-modal rainfall pattern with extended rainy season; from March to September. However the peak season is from July to August (Figure 1). The mean annual potential evapotranspiration, calculated by pan evaporation method (FAO, 1986), is about 1300 mm.

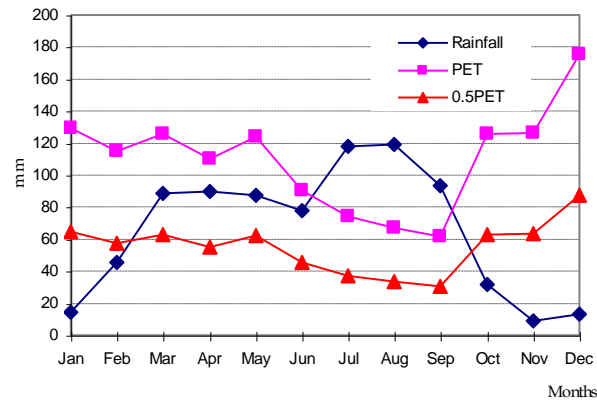


FIGURE 1. MEAN MONTHLY RAINFALL, PET AND 0.5PET AT KULUMSA

The mean annual maximum temperature is 23 °C and monthly values range between 21 and 25 °C. The mean annual minimum temperature is 10 °C and monthly values range between 8 and 12 °C. The coldest month is December whereas March is the hottest month.

As shown in the figure 1, in most months of the year (mid March to mid October) the rainfall is higher than the half potential evapotranspiration, thus endowing the area to have 200 to 240 consecutive days of LGP. During the months July to September the rainfall is higher than the full potential evapotranspiration. In general, the total rainfall during the growing season is about 700mm and the mean maximum and minimum temperatures are 23 and 11 °C, respectively.

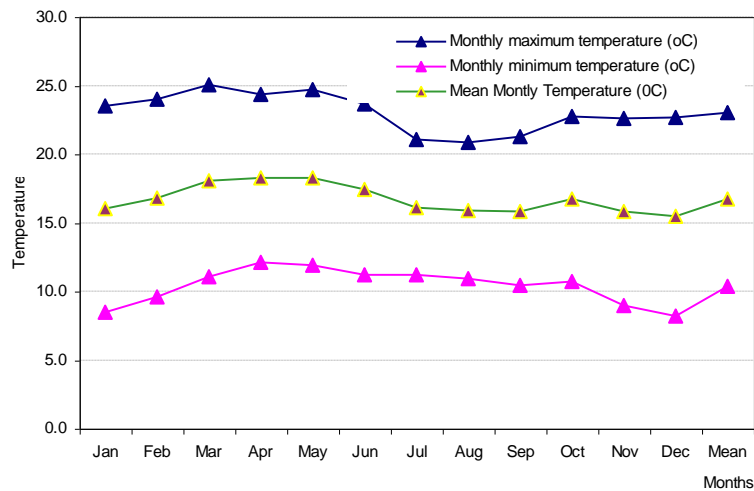


FIGURE 2. MAX, MIN., AND MEAN TEMPERATURE AT KULUMSA ARC

2.3 Soil Moisture and Temperature Regimes

Soil moisture and temperature records were not available at the time of survey. Thus, they were estimated on the basis of Length of Growing Period calculations (Figure 1) and the mean annual air temperature (Annex 1), respectively. The data indicate that the soil moisture regime can be classified as *Udic* and the soil temperature as *Isothermic* (as defined by USDA, 1975).

2.4 Physiography and Geology

The research center is located on a very gently undulating topography with a gradient of 0 to 10% slope. It has a low relief difference with altitude ranging from 1980 to 2230 meters. In some places where the slope is very flat, flooding and water logging occur.

The geology of the area consists of pyroclastic rocks, mainly tuffs and ignimbrites of the recent volcanic eruptions. The upper soil layer consists of tephritic materials, whereas the substratum consists of calcareous material enriched through secondary precipitation over the bedrock.

3. SURVEY METHODS

3.1 Office Work

Prior to commencement of the field soil investigation, a reconnaissance field visit has been made to the research center, during the time when the site layout was mapped. In addition, secondary data such as aerial photographs (AP's) and topographic maps were collected and analyzed. During site mapping altitude and geographic locations of block boundaries and important landmarks were recorded using geographical positioning system (GPS).

The research center and the surroundings are covered by approximately 1:50,000 scale black and white photography flown in December 1972. Aerial photo-interpretation was carried out both with a Topcon pocket and Mirror stereoscope to determine different land units on the basis of slope and other external land characteristics. In addition to aerial photos, topographic maps at 1:50,00 scale produced by the Ethiopian Mapping Authority in 1994 were used. These topographic maps were used for approximate location of the area and to study other important land features of the surrounding.

3.2 Field Work Procedure

The soil investigation fieldwork was conducted in two successive steps:

- a) **Auger observation:** After having the preliminary site and photo interpretation map verified, auger observations were made to study land and soil characteristics of the farmland. The augerings were made with "Edelman" auger to a depth of 1.2 m unless soil depth is limited or augering is impracticable due to stoniness. Auger observations were recorded on a standard form for auger description. The survey technique was a fixed-grid of 100m by 100m. In some irregular units additional observations were made to study the variability. Base lines of the grid system were oriented in such a way that observation traverses cut-across soil boundaries. In total 182 auger observations were made.
- b) **Profile sampling:** For further soil characterization, fifteen soil profile pits were dug on representative sites. The soil profile descriptions made according to FAO system were recorded on standard form for soil profile description. In total 65 samples were collected from natural soil horizons.

3.3 The Soil Map and Legend

Homogeneous land units have been distinguished on the basis of the following three major land/soil characteristics: slope, soil depth and surface soil texture. Slope percentage in the farm ranges from 0 to 10 and land facets were grouped according to their general slope classes at the first level of generalization. Following, soil depth, as it varies significantly within the farm, was considered to further group homogenous land units of the farm. Land with uniform slope and soil depth was further subdivided on the basis of surface texture. Thus, the soil map of the farm indicates areas that are uniform in slope, soil depth and surface texture (Table 1). In general, eleven different mapping units have been identified (Table 2).

Slope %		Soil depth (cm)		Surface Texture (0 - 30cm)	
Class	Code	Class	Code	Type	Code
0 - 2	1	> 150	a	Heavy clay	1
2 - 5	2	100 - 150	b	Clay	2
5 - 10	3	50 - 100	c	Silty clay	3
10 - 15	4	30 - 50	d	Clay loam	6
15 - 30	5	< 30	e	Sandy clay loam	7

TABLE 1. DISTINGUISHING CRITERIA OF THE MAPPING UNITS

On the soil map a land unit is indicated by at least three elements: a number indicating the first criterion (slope class), a lower case letter indicating the second criterion (soil depth class) and a number following the lower case letter indicates the third criterion (surface texture code).

1b2: wherein, 1-slope class, b-depth class and 2-surface texture

Mapping unit	Slope (%)	Soil depth (cm)	Texture (0 - 30 cm)	Area		Soil Units (FAO, 1990)
				ha	%	
1b2	0 - 2	100 - 150	Clay	106.39	39.54	Vertic Luvisol

2c2	0 - 2	50 - 100	Clay	3.55	1.32	Vertic Cambisol
2a1	2 - 5	> 150	Heavy clay	5.64	2.1	Eutric Vertisol
2b1	2 - 5	100 - 150	Heavy clay	21.43	7.96	Eutric Vertisol
2b2	2 - 5	100 - 150	Clay	81.18	30.17	Vertic Luvisol
3b2	5 - 10	100 - 150	Clay	18.1	6.73	Vertic Luvisol
3b6	5 - 10	100 - 150	Clay loam	7.96	2.96	Vertic Luvisol
3c2	5 - 10	50 - 100	Clay	9.45	3.51	Vertic Luvisol
3c6	5 - 10	50 - 100	Clay loam	0.43	0.16	Vertic Luvisol
4b2	10 - 15	100 - 150	Clay	1.73	0.64	Vertic Cambisol
5e7	15 - 30	< 30	Sandy clay loam	0.45	0.17	Lithic Leptosol
Compound				10.82	10.82	
Dairy Barren				0.47	0.47	
Eucalyptus Plantation				0.41	0.41	
Grass Land				1.06	1.06	
Total				269.07	100.00	

TABLE 2. LIST OF MAPPING UNITS IDENTIFIED IN THE RESEARCH CENTER

3.4 Laboratory Analyses

The soil samples collected were analyzed in the Soil Laboratory of the National Soil Research Center. All the soil samples were air-dried and ground to pass through 2mm sieve before analysis. The type of analysis and methods used are as follows.

Soil texture was determined by the modified Bouyoucos hydrometer method and pH was determined by pH meter in 1:2.5 soil-water suspension. Exchangeable bases were determined from a 1N ammonium acetate extract where calcium and magnesium were read by atomic absorption spectrometer; sodium and potassium by flamephotometer. Cation exchange capacity was determined by ammonium saturation method. Organic matter was determined by the Walkley-Black method, total nitrogen by the Macrokjeldahal method and available phosphorus by the Olsen method. Micronutrients (Fe, Mn, Zn and Cu) were determined by Diethylene Triamine Penta Acetic Acid (DTPA) extraction method and read by atomic absorption.

4. RESULTS AND DISCUSSION

4.1 Introduction

The soil-mapping units indicate the slope, soil depth and surface texture of a given site in the research farm. Soil type had less importance as a criterion for distinguishing mapping units because there are only three major soil types in the farm: vertisols, luvisols and cambisols.

The physico-chemical characteristics of the eleven mapping units are given in the subsequent sections. Summary characteristics of the mapping units are given in Table 3. Detailed analytical data of the soil profiles are given in Annex 3.

4.2 Physico-chemical Characteristics of the Mapping Units

The distribution of the different mapping units and soil units in the research farm is shown in figure 3 and figure 4 and the major physico-chemical properties of each soil units are given in Table 3. Each soil unit is briefly described below:

4.2.1 Mapping unit: 1b2

This unit refers to the well-drained soils that occur on flat plain with less than 2% slope in the central part of the farm. It covers 106.39 ha or 39.54% of the farm.

Soils of the unit are deep (100 to 150 cm) and very dark brown (10 YR2/1.5) in color. The texture is clay with strong coarse angular blocky structure. These soils have consistency that is friable when moist and sticky-plastic when wet.

The pH of surface soil is around 6, increasing to 8.4 in subsurface horizons and the electrical conductivity ranges between 0.02 and 0.13 mS/cm. The cation exchange capacity of the soils is high to very high (29 to 45 cmol (+)/kg soil) and it is moderately to highly base saturated (62 to 100%), increasing with depth. The organic matter and total nitrogen content decreases with depth and their values range from 0.02 to 2.74% for organic matter and 0.04 to 2.09% for total nitrogen; while available phosphorous is low (0 to 9.4 ppm). The values of available micronutrients (Fe, Mn, Zn and Cu) decrease with depth and their values range from 6 to 53 ppm for Fe, 4 to 36 for Mn, 0.2 to 1.1 for Zn and 0.6 to 2.0 for Cu.

4.2.2 Mapping Unit: 2a1

This unit refers to the moderately well drained soils that occur on gently sloping plain with 2 to 5% slope in the western part of the farm. It covers 5.64 ha or 2.1% of the farm.

Soils of the unit are very deep (> 150 cm) and very dark grayish brown (10YR3/2) in color. The texture is heavy clay with strong coarse angular blocky structure. These soils have consistency that is hard when dry, firm when moist and sticky- plastic when wet.

The pH of surface soil is around 6.1, increasing to 8.6 in subsurface horizons and the electrical conductivity ranges between 0.02 and 0.09 mS/cm. The cation exchange capacity of the soils is high and it is highly base saturated (40 to 50 cmol(+)/kg soil, and 88 to 100%, respectively). The total nitrogen content is high (0.56 to 2.69); while the organic matter and available phosphorous content is low (0.07 to 0.31% and 1.3 to 7.5 ppm, respectively). Available micronutrients range between 5 to 51ppm for Fe, 0 to 55 for Mn, 0.0 to 0.9 for Zn and 1.3 to 1.9 for Cu.

4.2.3 Mapping Unit: 2b1

This unit refers to the moderately well drained soils that occur on gently sloping land (2 to 5% slope) in the southeastern part of the farm. It covers 21.43 ha or 7.96% of the farm.

Soils of the unit are deep (100 to 150 cm) and black (10YR2/1) in color. The texture is heavy clay with strong medium angular blocky structure. These soils have consistency that is hard when dry, friable when moist and sticky- plastic when wet.

The pH of surface soil is around 6.4, increasing to 8.5 in subsurface horizons and the electrical conductivity ranges between 0.03 and 0.19 mS/cm. The cation exchange capacity of the soils is high and it is highly base saturated (34 to 48 cmol(+)/kg soil, and 91 to 100%, respectively). The organic matter and total nitrogen content ranges from 0.05 to 0.31 and 0.29 to 2.22%, respectively; while available phosphorous is low (0.0 to 11.7 ppm). Available micronutrients range between 4 to 48 ppm for Fe, 0 to 71 for Mn, 0.1 to 1.0 for Zn and 1.1 to 2.3 for Cu.

4.2.4 Mapping Unit: 2b2

This unit refers to the well-drained soils that occur on gently sloping land (2 to 5% slope) in the eastern and western parts of the farm. It covers 81.18 ha or 30.17% of the farm.

Soils of the unit are deep (100 to 150 cm) and black (10YR2/1) to dark brown (7.5YR3/2) in color. The texture is clay with moderate coarse sub angular blocky structure. These soils have consistency that is hard when dry, friable when moist and slightly sticky-slightly plastic when wet.

The pH of surface soil is around 5.9, increasing to 8.3 in subsurface horizons and the electrical conductivity ranges between 0.02 and 0.16 mS/cm. The cation exchange capacity of the soils is high and it is highly base saturated (31 to 46 cmol(+)/kg soil, and 78 to 100%, respectively). The organic matter and total nitrogen content ranges from 0.06 to 0.34 and 0.14 to 2.95%, respectively; while available phosphorous is low (0.5 to 11.5 ppm). Available micronutrients range between 6 to 48 ppm for Fe, 0 to 74 for Mn, 0.1 to 1.7 for Zn and 0.4 to 1.9 for Cu.

4.2.5 Mapping Unit: 2c2

This unit refers to the well-drained soils that occur on gently sloping land (2 to 5% slope) in the northeastern part of the farm. It covers 3.55 ha or 1.32% of the farm.

Soils of the unit are moderately deep (50 to 100 cm) and dark reddish brown (5R3/2) in color. The texture is clay with strong coarse angular blocky structure. These soils have consistency that is hard when dry, friable when moist and sticky-slightly plastic when wet.

The pH of surface soil is around 6.6, increasing to 8.6 in subsurface horizons and the electrical conductivity ranges between 0.03 and 0.15 mS/cm. The cation exchange capacity of the soils is high and it is highly base saturated (32 to 38 cmol (+)/kg soil, and 68 to 100%, respectively). The organic matter and total nitrogen content ranges from 0.69 to 3.61 and 0.06 to 0.15%, respectively; while available phosphorous is low (0.4 to 3.8 ppm). Available micronutrients range between 5 to 39 ppm for Fe, 6 to 70 for Mn, 0.2 to 0.9 for Zn and 0.6 to 1.8 for Cu.

4.2.6 Mapping Unit: 3b2

This unit refers to the well-drained soils that occur on sloping land (5 to 10% slope) in the western and northern part of the farm. It covers 18.1 ha or 6.73% of the farm.

Soils of the unit are deep (100 to 150 cm) and dark reddish brown (5YR2.5/2) in color. The texture is clay with strong coarse sub- angular blocky structure. These soils have consistency that is hard when dry, friable when moist and slightly sticky slightly plastic when wet.

The pH of surface soil is around 6.1, increasing to 8.4 in subsurface horizons and the electrical conductivity ranges between 0.02 and 0.08 mS/cm. The cation exchange capacity of the soils is high and it is highly base saturated (36 to 44 cmol(+)/kg soil, and 84 to 100%, respectively). The organic matter and total nitrogen content ranges from 0.07 to 0.26 and 0.28 to 2.07%, respectively; while available phosphorous is low (0.7 to 8.1 ppm). Available micronutrients range between 6 to 28 ppm for Fe, 0 to 55 for Mn, 0.1 to 1.1 for Zn and 0.3 to 1.8 for Cu.

4.2.7 Mapping Unit: 3b6

This unit refers to the well-drained soils that occur on sloping land (5 to 10% slope) in the western part of the farm. It covers 7.96 ha or 2.96% of the farm.

Soils of the unit are deep (100 to 150 cm) and very dark grayish brown (10YR3/2) in color. The texture is clay loam with moderate medium crumb structure. These soils have consistency that is hard when dry, friable when moist and slightly sticky slightly plastic when wet.

The pH of surface soil is around 6.1 increasing to 8.3 in subsurface horizons and the electrical conductivity ranges between 0.03 and 0.06 mS/cm. The cation exchange capacity of the soils is high and it is highly base saturated (34 to 41 cmol (+)/kg soil, and 83 to 98%, respectively). The organic matter and total nitrogen content ranges from 0.02 to 0.31 and 0.14 to 2.51%, respectively; while available phosphorous is low (1.0 to 7.2 ppm). Available micronutrients range between 6 to 43 ppm for Fe, 0 to 74 for Mn, 0.2 to 0.8 for Zn and 0.5 to 1.9 for Cu.

4.2.8 Mapping Unit: 3c2

This unit refers to the well-drained soils that occur on sloping land (5 to 10% slope) in the different parts of the farm. It

covers 9.45 ha or 3.51% of the farm.

Soils of the unit are moderately deep (50 to 100 cm) and reddish brown (5YR3/2) in color. The texture is clay with moderate coarse sub angular blocky structure. These soils have consistency that is hard when dry, friable when moist and sticky plastic when wet.

The pH of surface soil is 6.1 increasing to 8.8 in subsurface horizons and the electrical conductivity ranges between 0.05 and 0.20 mS/cm. The cation exchange capacity is high and it is highly base saturated (30 to 43 cmol(+)/kg soil, and 75 to 100%, respectively). The organic matter and total nitrogen content ranges from 0.55 to 3.89 and 0.03 to 0.16%, respectively; while available phosphorous is very low. Available micronutrients range from 7 to 32 ppm for Fe, 5 to 72 for Mn, 0.5 to 0.6 for Zn and 0.5 to 1.1 for Cu.

4.2.9 Mapping Unit: 3c6

This unit refers to the well-drained soils that occur on sloping land (5 to 10% slope) in the southeastern part of the farm. It covers 0.43 ha or 0.16% of the farm.

Soils of the unit are moderately deep (50 to 100 cm) and very dark reddish brown (5YR3/2) in color. The texture is clay loam with strong coarse sub angular blocky structure. These soils have consistency that is hard when dry, firm when moist and slightly sticky slightly plastic when wet.

The pH of surface soil is around 6.3 increasing to 7.6 in subsurface horizons and the electrical conductivity ranges between 0.04 and 0.06 mS/cm. The cation exchange capacity of the soils is high and it is moderately base saturated (36 to 42 cmol(+)/kg soil, and 64 to 75%, respectively). The organic matter and total nitrogen content ranges from 0.69 to 4.29 and 0.03 to 1.00%, respectively; while available phosphorous is low (0.8 to 11.6 ppm). Available micronutrients range between 15 to 53 ppm for Fe, 11 to 90 for Mn, 0.6 to 1.8 for Zn and 0.3 to 1.6 for Cu.

4.2.10 Mapping Unit: 4b2

This unit refers to the well-drained soils that occur on moderately steep land (10 to 15% slope) in the western part of the farm. It covers 1.73 ha or 0.64% of the farm.

Soils of the unit are deep (100 to 150 cm) and very dark grayish brown (10YR3/2) in color. The texture is clay with strong medium angular blocky structure. These soils have consistency that is hard when dry, friable when moist and sticky plastic when wet.

The pH of surface soil is around 6.3, increasing to 7.7 in subsurface horizons and the electrical conductivity ranges between 0.07 and 0.15 mS/cm. The cation exchange capacity of the soils is high and it is highly base saturated (33 to 43 cmol(+)/kg soil, and 75 to 98%, respectively). The organic matter and total nitrogen content ranges from 0.34 to 4.80 and 0.02 to 1.00%, respectively; while available phosphorous is between 0.0 to 56.0 ppm). Available micronutrients range between 10 to 41 ppm for Fe, 10 to 62 for Mn, 0.3 to 2.7 for Zn and 0.1 to 1.7 for Cu.

4.2.11 Mapping Unit: 5e7

This unit refers to the somewhat excessively drained soils that occur on steep land (15 to 30% slope) in the western part of the farm. It covers 0.45 ha or 0.17% of the farm.

Soils of the unit are very shallow (<30 cm) and very dark grayish brown (10R3/2) in color. The texture is sandy clay loam with massive structure. These soils have consistency that is soft when dry, friable when moist and slightly sticky non-plastic when wet.

Mapping Unit	Slope %	Soil depth (cm)	Texture (0-30 cm)	pH H ₂ O	EC mS/cm	OM %	T.N %	Av. P ppm
1b2	<2	100-150	Clay	6.3-8.4	0.02-0.13	0.02-2.74	0.04-2.09	0.0-9.4
2a1	2-5	>150	Heavy clay	6.1-8.6	0.02-0.09	0.07-0.31	0.56-2.69	1.3-7.5
2b1	2-5	100-150	Heavy clay	6.4-8.5	0.03-0.19	0.05-0.31	0.29-2.22	0.0-11.7
2b2	2-5	100-150	Clay	5.9-8.3	0.02-0.16	0.06-0.34	0.14-2.95	0.5-11.5
2c2	2-5	50-100	Clay	6.6-8.6	0.03-0.15	0.69-3.61	0.06-0.15	0.4-3.8
3b2	5-10	100-150	Clay	6.1-8.4	0.02-0.08	0.07-0.26	0.28-2.07	0.7-8.1
3b6	5-10	100-150	Clay loam	6.1-8.3	0.03-0.06	0.02-0.31	0.14-2.51	1.0-7.2
3c2	5-10	50-100	Clay	6.1-8.8	0.05-0.20	0.55-3.89	0.03-0.16	Trace
3c6	5-10	50-100	Clay loam	6.3-7.6	0.04-0.06	0.69-4.29	0.03-1.00	0.8-11.6
4b2	10-15	100-150	Clay	6.3-7.7	0.07-0.15	0.34-4.80	0.02-1.00	0.0-56.0
5e7	15-30	<30	Sandy clay loam					

Mapping	Exchangeable bases (cmol (+) kg ⁻¹ soil)	BSP	ESP	Micronutrients (ppm)
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Unit	Na	K	Ca	Mg	CEC		Fe	Mn	Zn	Cu	
1b2	0.3-1.7	1.2-4.2	15-33	4-8	29-45	62-100	1.0-4.7	6-53	4-36	0.2-1.1	0.6-2.0
2a1	0.8-3.1	1.8-2.0	25-44	7-9	40-50	88-100	2.1-6.2	5-51	0-55	0.0-0.9	1.3-1.9
2b1	1.2-3.1	1.6-3.6	21-40	5-9	34-48	91-100	3.0-7.0	4-48	0-71	0.1-1.0	1.1-2.3
2b2	0.5-2.5	1.4-3.2	21-38	5-7	31-46	78-100	1.5-6.0	6-48	0-74	0.1-1.7	0.4-1.9
2c2	0.4-0.8	2.1-3.2	18-26	5-6	32-38	68-100	1.0-2.4	5-39	6-70	0.2-0.9	0.6-1.8
3b2	0.8-1.6	1.7-2.1	23-41	5-7	36-44	84-100	2.1-6.7	6-28	0-55	0.1-1.1	0.3-1.8
3b6	0.7-2.3	1.5-2.9	19-30	4-6	34-41	83-98	2.0-6.2	6-43	0-74	0.2-0.8	0.5-1.9
3c2	0.5-1.8	0.5-1.6	21-22	5-11	30-43	75-100	1.2-4.3	7-32	5-72	0.5-0.6	0.5-1.1
3c6	0.3-0.5	1.6-4.0	16-18	5-6	36-42	64-75	0.1-1.1	15-53	11-90	0.6-1.8	0.3-1.6
4b2	0.2-1.8	1.7-4.8	21-31	4-6	33-43	75-98	0.6-4.3	10-41	10-62	0.3-2.7	0.1-1.7
5e7											

TABLE 3. SUMMARY CHARACTERISTICS OF THE MAPPING UNITS

4.3 Soil Classification

The fifteen soil profile pits (pedons) dug on representative site in each of the mapping units were classified according to the 1990 version of the FAO/UNESCO soil classification system. Despite the darker soil color, soft structure and high base saturation, all the soils of the research center have an ochric epipedon due to low organic carbon content. Argic B horizon with high base saturation is the most common subsurface diagnostic horizon occurring between 30 and 100 cm from surface. Cambic B horizon was also recognized in some pedons. In general there are three soil units recognized in the research center: Vertic Luvisol, Eutric Vertisol and Vertic Cambisol. The result of the classification exercise has been summarized in Table 4.

Mapping Units	Pedon No.	Diagnostic Horizons		Soil Units (FAO, 1990)
		Epipedon	Subsurface	
1b2	K9, K14	Ochric	Argic	Vertic Luvisol
2a1	K6	Ochric	Vertic property	Eutric Vertisol
2b1	K8	Ochric	Vertic property	Eutric Vertisol
2b2	K1, K4, K5	Ochric	Argic	Vertic Luvisol
2c2	K13	Ochric	Cambic	Vertic Cambisol
3b2	K2, K3	Ochric	Argic	Vertic Luvisol
3b6	K7	Ochric	Argic	Vertic Luvisol
3c2	K12	Ochric	Argic	Vertic Luvisol
3c6	K15	Ochric	Argic	Vertic Luvisol
4b2	K10, K11	Ochric	Cambic	Vertic Cambisol
5e7	-	Ochric	Lithic	Lithic Leptosol

TABLE 4. SOIL UNITS RECOGNIZED IN KULUMSA AGRICULTURAL RESEARCH CENTER BY MAPPING UNIT

FIGURE 3. MAPPING UNIT OF KULUMSA AGRICULTURAL RESEARCH CENTER

FIGURE 4. SOIL MAP OF KULUMSA AGRICULTURAL RESEARCH CENTER

5. OVERALL SOIL PHYSICAL AND CHEMICAL CHARACTERISTICS

5.1 Physical Properties

5.1.1 Texture

The results of the particle size analysis indicate that the majority of the soils within the farm are medium to heavy textured containing higher proportions of clay, particularly in the B-horizons. This could probably be due to possible clay migration within the profile. The textural classes of the soils are *heavy clay, clay, silty clay, clay loam and sandy clay loam*.

5.1.2 Soil structure

The surface soil layers (0 to 30 cm) of the farm have sub angular structure while the subsurface soil layers have strongly developed angular blocky structure with good porosity.

5.1.3 Soil depth

There is a significant difference in soil depth to bedrock within the farm. It was one of the criteria used to distinguish mapping units within the farm. In general, four soil depth classes have been identified: *very shallow* (<30cm), *moderately deep* (50 to 100cm), *deep* (100 to 150cm) and *very deep* (>150cm). About 92.5% of the farmland has a soil depth ranging between 100 and 150 cm. The very deep and the very shallow soils cover not more than 2.5% of the total area, while moderately deep soils cover 5% of the farm.

5.2 Chemical Properties

5.2.1 Soil reaction

Soils of the farm have moderately acidic to moderately alkaline reactions, pH values ranging between 5.9 and 8.8. In general, pH values tend to increase with depth and pH values of the surface layers (0 to 30 cm) range between 5.9 and 6.6.

5.2.2 Organic matter

The organic matter content of surface layers (0 to 30cm) is low to medium, ranging between 0.31 to 4.8%. In the subsurface horizons its content decreases to about 0.02 to 0.7%.

5.2.3 Nitrogen

The total nitrogen content of the topsoil is generally high (greater than 0.15%). However, its content decreases same as organic matter with depth to about 0.02 to 0.3% (which is low).

5.2.4 Phosphorous

The available phosphorous content decreases with depth. Its content in the surface layers range between 3 and 12 ppm, exceptionally high value (56 ppm) was determined in one of the pedons. In subsurface soil layers (below 30 cm), the available phosphorous content decreases to 0 to 1.3 ppm.

5.2.5 Cation exchange capacity

The cation exchange capacity of the soils ranges between 29 and 50 cmol(+) kg⁻¹ soil. The amount of CEC correlates with the clay content in the profile.

5.2.6 Cation balance

Soils of the farmland are highly base saturated. However, this does not prove a balanced proportion of the exchangeable bases. Thus, the ratio of the cations was examined to evaluate the status of the relative proportions of cations. The ratios of Ca to Mg, Mg to K, and Ca+Mg to K range between 3 to 11, 1 to 5 and 4 to 30, respectively in the upper 30 cm of the soils. According to B. Frank (1990), these ratios indicate that there is a favorable balance between Ca and Mg. However, both Mg to K and Ca+Mg to K ratios indicate that Ca and Mg may likely be deficient.

5.2.7 Exchangeable sodium percentage

The exchangeable sodium content of the soils range from 0.3 to 3.2 cmol(+) kg⁻¹ and its content increases with depth. Correspondingly, the exchangeable sodium percentage (ESP) of the soils ranges from 1 to 7.

5.2.8 Micronutrients

The content of available micronutrients (Fe, Mn, Zn and Cu) tends to decrease with depth. Soils of the farm contain Fe and Mn in relatively high amounts; the levels in the surface layers normally falling in the range of 12 to 53 and 50 to 135 ppm, respectively. This is probably due to the slightly acidic soil reaction, which likely increases their solubility. On the other hand, the amount of Zn and Cu is low; the levels in the surface layers normally falling in the range of 0.5 to 3 and 1.1 to 2.3 ppm, respectively. This could be due to the nature of the parent material, which has resulted absolute low contents in the soils.

Summery

Soils of the Kulumsa Agricultural Research Center, located in Arsi zone of the Oromia Region at about 170km south of Addis Ababa, were surveyed by fixed-grid technique at 100 by 100m intensity (1:10,000 scale). The total area of the experimental field is about 269ha. Eleven soil-mapping units were identified on the basis of surface slope, soil depth and

surface soil structure. For detail characterization and classification of the soils in the mapping units 15 pedons were described and sampled by horizon for laboratory analyses.

There are three major soil types - Eutric Vertisol, Vertic Luvisol and Vertic Cambisol - (FAO, 1990) in the research center. In general soils of the research center have acidic surface soil reaction that progressively becomes alkaline with depth. The organic matter and total nitrogen content decrease with depth. The exchange complex of the soils is within the acceptable range. However, the available phosphorous, zinc and copper content is low in all the soil units.

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Annex 1. Soil profile descriptions

DATE: 19/4/00

FIELD NO: K1

PROJECT: Kulumsa Research Center

LOCATION: Block No. 30

ALTITUDE: 2240 m

COORDINATES: N 08°00'55" E 39°09'28"

AUTHOR (S): Kebede A. and Gebeyehu B.

SOIL CLASSIFICATION: Vertic Luvisols

SURROUNDING LANDFORM: Almost flat plain

PHYSIOGRAPHIC POSITION: Upper Slope

LAND USE/COVER: Maize field

SLOPE GRADIENT: >2%

MOISTURE CONDITION: Slightly moist below 30 cm

DRAINAGE CLASS: Well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Pyroclastic

EROSION STATUS: None

CLIMATE: Tepid to cool sub-moist

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0 - 30 cm	Black (10YR2/1) moist and dark brown (7.5YR3/2) dry, clay; moderate coarse sub-angular blocky; slightly sticky slightly plastic wet, friable moist, hard dry; few coarse interstitial pores; very few fine roots; clear and smooth boundary.
Bt 30 - 100 cm	Dark reddish brown (5YR2.5/2) moist, clay; moderate medium angular blocky; sticky plastic wet, slightly firm moist; dominant prominent clay cutans; few fine interstitial pores; very few angular gravel; very few fine roots; clear and wavy boundary.
Bc 100 - 125 cm	Dark reddish brown (5YR3/2) moist, clay; moderate medium angular blocky; sticky plastic wet, friable moist; many distinct clay cutans; common fine interstitial pores.
C > 125 cm	Highly weathered rock.

FIELD NO: K2
 PROJECT: Kulumsa Research Center
 LOCATION: Block No. 40
 ALTITUDE: 2140 m
 COORDINATES: N 8° 01'25" E 39°09'13"
 AUTHOR (S): Kebede A. and Gebeyehu B.
 SOIL CLASSIFICATION: Vertic Luvisols
 SURROUNDING LANDFORM: Undulating plateau
 PHYSIOGRAPHIC POSITION: Upper Slope
 LAND USE/COVER: Wheat field
 SLOPE GRADIENT: <10%
 MOISTURE CONDITION: Slightly moist below 25 cm
 DRAINAGE CLASS: Well drained
 GROUNDWATER DEPTH: Not observed
 PARENT MATERIAL: Pyroclastic
 EROSION STATUS: None
 CLIMATE: Tepid to cool sub-moist
 ROCK OUTCROPS: None
 SURFACE STONES: None

Profile Description

Ap 0 - 25 cm	Dark reddish brown (5YR2.5/2) moist and dark brown (7.5YR3/2) dry, clay; strong coarse sub-angular blocky; wide closely spaced cracks; slightly sticky slightly plastic wet, friable moist, hard dry; common fine interstitial pores; common fine sub-rounded gravels; common fine roots; clear and smooth boundary.
Bt 25 - 80 cm	Dark reddish brown (5YR2.5/2) moist, clay; strong coarse angular blocky; sticky plastic wet, firm moist; abundant prominent clay cutans; few fine interstitial pores; few medium angular gravel; common fine roots; clear and wavy boundary.
Bc 80 - 110 cm	Dark reddish brown (5YR3/2) moist, clay; strong coarse angular blocky; sticky plastic wet, friable moist; common distinct clay cutans; very few fine interstitial pores.
C > 110 cm	Highly weathered rock.

FIELD NO: K3
PROJECT: Kulumsa Research Center
LOCATION: Block No. 90
ALTITUDE: 2100 m
COORDINATES: N 08° 01' 13" E 39°08'14"
AUTHOR (S): Kebede A. and Gebeyehu B.
SOIL CLASSIFICATION: Vertic Luvisols
SURROUNDING LANDFORM: Undulating plateau
PHYSIOGRAPHIC POSITION: Middle slope
LAND USE/COVER: Wheat field
SLOPE GRADIENT: >5%
MOISTURE CONDITION: Moist below 30 cm
DRAINAGE CLASS: Well drained
GROUNDWATER DEPTH: Not observed
PARENT MATERIAL: Pyroclastic
EROSION STATUS: None
CLIMATE: Tepid to cool sub-moist
ROCK OUTCROPS: None
SURFACE STONES: None

Profile Description

Ap 0 - 30 cm	Dark reddish brown (5YR2.5/2) moist and dark brown (7.5YR3/2) dry, clay; strong coarse sub-angular blocky; sticky slightly plastic wet, friable moist, hard dry; many fine interstitial pores; common fine roots; wide closely spaced cracks; clear and smooth boundary.
Bt 30 - 95 cm	Dark reddish brown (5YR2.5/2) moist, clay; strong coarse angular blocky; sticky plastic wet, firm moist; abundant prominent clay cutans; common fine interstitial pores; common fine roots; clear and wavy boundary.
Bc 95 - 135 cm	Dark reddish brown (5YR3/2) moist, clay; strong coarse angular blocky; sticky plastic wet, friable moist; abundant prominent clay cutans; few very fine interstitial pores; very few fine rock fragments; clear and smooth boundary.
C > 135 cm	Highly weathered rock.

FIELD NO: K4
 PROJECT: Kulumsa Research Center
 LOCATION: Block No. 100
 ALTITUDE: 2120 m
 COORDINATES: N 08°01'06" E 39°08'32"
 AUTHOR (S): Kebede A. and Gebeyehu B.
 SOIL CLASSIFICATION: Vertic Luvisols
 SURROUNDING LANDFORM: Gently undulating plateau
 PHYSIOGRAPHIC POSITION: Upper slope
 LAND USE/COVER: Horse bean field
 SLOPE GRADIENT: 4%
 MOISTURE CONDITION: Moist below 30 cm
 DRAINAGE CLASS: Well drained
 GROUNDWATER DEPTH: Not observed
 PARENT MATERIAL: Pyroclastic
 EROSION STATUS: None
 CLIMATE: Tepid to cool sub-moist
 ROCK OUTCROPS: None
 SURFACE STONES: None

Profile Description

Ap 0 - 25 cm	Dark brown (7.5YR3/2) dry and black (5YR2.5/1) moist, clay; strong coarse sub-angular blocky; sticky slightly plastic wet, friable moist, hard dry; many fine interstitial pores; many fine roots; clear and smooth boundary.
Bt 25 - 100 cm	Dark reddish brown (5YR2.5/2) moist, clay; strong coarse angular blocky; sticky plastic wet, friable moist; few faint clay cutans; common fine interstitial pores; few fine roots; clear and wavy boundary.
Bc 100 - 135 cm	Dark reddish brown (5YR3/2) moist, clay; strong coarse angular blocky; sticky plastic wet, friable moist; abundant prominent clay cutans; few very fine interstitial pores; clear and smooth boundary.
C > 135 cm	Highly weathered rock.

FIELD NO: K5
 PROJECT: Kulumsa Research Center
 LOCATION: Block No. 160
 ALTITUDE: 2110 m
 COORDINATES: N 08°00'54" E 39° 07'52"
 AUTHOR (S): Kebede A. and Gebeyehu B.
 SOIL CLASSIFICATION: Vertic Luvisols
 SURROUNDING LANDFORM: Undulating plateau
 PHYSIOGRAPHIC POSITION: Middle slope
 LAND USE/COVER: Wheat field
 SLOPE GRADIENT: <5%
 MOISTURE CONDITION: Moist below 45 cm
 DRAINAGE CLASS: Well drained
 GROUNDWATER DEPTH: Not observed
 PARENT MATERIAL: Pyroclastic
 EROSION STATUS: None
 CLIMATE: Tepid to cool sub-moist
 ROCK OUTCROPS: None
 SURFACE STONES: None

Profile Description

Ap 0 - 25 cm	Dark brown (7.5YR3/2) dry and dark reddish brown (5YR2.5/2) moist, clay; strong coarse sub-angular blocky; slightly sticky slightly plastic wet, friable moist, hard dry; common fine interstitial pores; many fine roots; clear and smooth boundary.
A 25 - 45 cm	Very dark gray (5YR3/1) dry and black (5YR2.5/1) moist, clay; strong coarse sub-angular blocky; sticky slightly plastic wet, friable moist, slightly hard dry; common fine interstitial pores; common fine roots; clear and smooth boundary.
B 45 - 70 cm	Dark reddish brown (5YR3/2) moist, clay; strong coarse sub-angular blocky; sticky plastic wet, friable moist; common fine interstitial pores; few faint shiny ped faces; few fine and very few fine roots; clear and smooth boundary.
Bt1 70 - 115 cm	Dark reddish brown (5YR 2.5/2) moist, clay; strong coarse angular blocky; stick plastic wet, friable moist; common distinct clay cutans; common fine interstitial pores; clear and wavy boundary.
Bt2 115 - 145 cm	Dark reddish brown (5YR3/2) moist, clay; strong coarse angular blocky; sticky plastic wet, friable moist; common distinct pressure faces; few fine interstitial pores; few fine sub-rounded rock fragments; clear and smooth boundary.
C > 145 cm	Highly weathered rock.

FIELD NO: K6

PROJECT: Kulumsa Research Center

LOCATION: Block No. 170

ALTITUDE: 2110 m

COORDINATES: N 08° 00'46" E 39°07'58"

AUTHOR (S): Kebede A. and Gebeyehu B.

SOIL CLASSIFICATION: Eutric Vertisols

SURROUNDING LANDFORM: Undulating plateau

PHYSIOGRAPHIC POSITION: Lower slope

LAND USE/COVER: Wheat field

SLOPE GRADIENT: 4%

MOISTURE CONDITION: Moist below 45 cm

DRAINAGE CLASS: Moderately well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Pyroclastic

EROSION STATUS: None

CLIMATE: Tepid to cool sub-moist

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0 - 30 cm	Very dark grayish brown (10YR3/2) dry and very dark brown (10YR2/2) moist, clay; strong coarse prismatic; Very closely spaced cracks; sticky plastic wet, firm moist, very hard dry; common fine interstitial pores; common fine roots; clear and smooth boundary.
A 30 - 75 cm	Black (10YR2/1) dry and moist, clay; strong coarse angular blocky; very sticky very plastic wet, firm moist, very hard dry; common fine interstitial pores; few fine roots; clear and wavy boundary.
B1 75 - 150 cm	Very dark brown (10YR2/2) moist, clay; strong coarse angular blocky; very sticky very plastic wet, friable moist; common prominent slickensides and pressure faces; few fine interstitial pores; clear and wavy boundary.
Btc 150 - 200 cm	Very dark grayish brown (10YR3/2) moist, clay; strong coarse angular blocky; sticky plastic wet, friable moist; common prominent slickensides and pressure faces; few fine interstitial pores; common CaCO ₃ concretions.

FIELD NO: K7
 PROJECT: Kulumsa Research Center
 LOCATION: Block No. 50
 ALTITUDE: 2170 m
 COORDINATES: N 08° 01'56" E 39°09'14"
 AUTHOR (S): Kebede A. and Gebeyehu B.
 SOIL CLASSIFICATION: Vertic Luvisols
 SURROUNDING LANDFORM: Undulating plateau
 PHYSIOGRAPHIC POSITION: Middle slope
 LAND USE/COVER: Vetch field
 SLOPE GRADIENT: 8%
 MOISTURE CONDITION: Slightly moist below 35 cm
 DRAINAGE CLASS: Well drained
 GROUNDWATER DEPTH: Not observed
 PARENT MATERIAL: Pyroclastic
 EROSION STATUS: None
 CLIMATE: Tepid to cool sub-moist
 ROCK OUTCROPS: None
 SURFACE STONES: None

Profile Description

Ap 0 - 20 cm	Very dark grayish brown (10YR3/2) dry and black (10YR2/1) moist, clay loam; moderate medium crumb; medium closely spaced cracks; slightly sticky slightly plastic wet, friable moist, hard dry; many fine interstitial pores; many fine roots; diffuse and smooth boundary.
A 20 - 50 cm	Black (10YR2/1) moist, clay; strong medium angular blocky; sticky slightly plastic wet, slightly firm moist; medium closely spaced cracks; common fine and medium interstitial pores; many fine roots; gradual and smooth boundary.
Bht 50 - 90 cm	Very dark brown (10YR2/2) moist, clay; strong coarse columnar; sticky slightly plastic wet, firm moist; medium closely spaced cracks; common distinct clay and humus cutans; few fine and common medium interstitial pores; many fine roots; clear and smooth boundary.
Bt 90 - 110 cm	Dark reddish brown (5YR3/2) moist, clay; strong medium angular blocky; sticky slightly plastic wet, firm moist; common distinct clay cutans; few fine and common medium interstitial pores; many fine roots; clear and smooth boundary.
C 110+ cm	Dark brown (7.5YR3/4) moist, clay loam; massive; sticky non-plastic wet, friable moist; many fine interstitial pores; few medium angular rock fragments.

FIELD NO: K8

PROJECT: Kulumsa Research Center

LOCATION: Block No. 120

ALTITUDE: 2140 m

COORDINATES: N 08°01'05" E 39° 09'03"

AUTHOR (S): Kebede A. and Gebeyehu B.

SOIL CLASSIFICATION: Eutric Vertisols

SURROUNDING LANDFORM: Gently undulating plateau

PHYSIOGRAPHIC POSITION: Middle slope

LAND USE/COVER:

SLOPE GRADIENT: 2.5%

MOISTURE CONDITION: Slightly moist below 35 cm

DRAINAGE CLASS: Moderately well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Pyroclastic

EROSION STATUS: None

CLIMATE: Tepid to cool sub-moist

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0 - 5 cm	Black (10YR2/1) moist and dark gray (10YR4/1) dry, silty clay; weak fine granular; fine to medium closely spaced cracks; sticky plastic wet, friable moist, slightly hard dry; many fine to medium interstitial pores; many medium to fine roots; clear and smooth boundary.
A1 5 - 90 cm	Very dark gray (10YR3/1) moist, clay; strong medium angular blocky; fine to medium closely spaced cracks; sticky plastic wet, friable moist; common faint slickensides and pressure faces; many fine and common coarse interstitial pores; many fine roots; gradual and smooth boundary.
B1 90 - 120 cm	Black (10YR2/1) moist, clay; strong medium angular blocky; fine to medium closely spaced cracks; sticky plastic wet, firm moist; common faint slickensides and pressure faces; common medium to coarse interstitial pores; common fine roots; clear and smooth boundary.
B2 120 - 140 cm	Very dark brown (10YR2/2) moist, clay; moderate medium sub-angular blocky; sticky plastic wet, friable moist; common distinct clay cutans; common fine and medium interstitial pores; few fine roots; clear and smooth boundary.
C 140+ cm	Brown (10YR5/4) moist, gravely clay; massive; sticky non-plastic wet, friable moist; many medium interstitial pores; many medium rock fragments; many calcium carbonate concretions.

FIELD NO: K9
 PROJECT: Kulumsa Research Center
 LOCATION: Block No. 70
 ALTITUDE: 2140 m
 COORDINATES: N 08°01'20" E 39° 08'54"
 AUTHOR (S): Kebede A. and Gebeyehu B.
 SOIL CLASSIFICATION: Vertic Luvisols
 SURROUNDING LANDFORM: Almost flat plateau
 PHYSIOGRAPHIC POSITION: Middle slope
 LAND USE/COVER: Rapeseed field
 SLOPE GRADIENT: 1%
 MOISTURE CONDITION: Slightly moist below 30 cm
 DRAINAGE CLASS: well drained
 GROUNDWATER DEPTH: Not observed
 PARENT MATERIAL: Pyroclastic
 EROSION STATUS: None
 CLIMATE: Tepid to cool sub-moist
 ROCK OUTCROPS: None
 SURFACE STONES: None

Profile Description

Ap 0 - 30 cm	Black to very dark brown (10YR2/1.5) moist and very dark grayish brown (10YR3/2) dry, clay; strong coarse angular blocky; fine to medium very closely spaced cracks; slightly sticky slightly plastic wet, friable moist, hard dry; many fine interstitial pores; many fine and very few fine roots; clear and smooth boundary.
Bt1 30 - 85 cm	Black (5YR2.5/1) moist, clay; strong coarse prismatic; moderate widely spaced cracks; sticky plastic wet, firm moist, hard dry; common distinct pressure faces; common fine interstitial pores; many very fine and few fine roots; clear and smooth boundary.
Bt2 85 - 140 cm	Dark reddish brown (5YR2.5/2) moist, clay; strong coarse prismatic; sticky plastic wet, friable moist; abundant prominent pressure faces; common fine pores; very few fine sub-rounded gravels; common very fine roots; clear and smooth boundary.
C > 140 cm	Highly weathered rock.

FIELD NO: K10
PROJECT: Kulumsa Research Center
LOCATION: Block No. 50
ALTITUDE: 2125 m
COORDINATES: N 08°01'04" E 39°09'26"
AUTHOR (S): Kebede A. and Gebeyehu B.
SOIL CLASSIFICATION: Vertic Cambisols
SURROUNDING LANDFORM: strongly sloping plateau
PHYSIOGRAPHIC POSITION: Middle slope
LAND USE/COVER: Grassland
SLOPE GRADIENT: 11%
MOISTURE CONDITION: dry 0-55 cm, moist below
DRAINAGE CLASS: well drained
GROUNDWATER DEPTH: Not observed
PARENT MATERIAL: Pyroclastic
EROSION STATUS: None
CLIMATE: Tepid to cool sub-moist
ROCK OUTCROPS: None
SURFACE STONES: None

Profile Description

Ap 0 - 20 cm	Very dark grayish brown (10YR3/2) moist and dark grayish brown (10YR4/2) dry, clay; strong medium angular blocky; medium very closely spaced cracks; sticky plastic wet, friable moist, hard dry; common fine interstitial pores; many fine roots; gradual and smooth boundary.
B1 20-55 cm	Black (10YR2/1) moist and black (10YR2/1) dry; clay; strong medium angular blocky; sticky plastic wet, firm moist, hard dry; common fine interstitial pores; common fine roots; clear and wavy boundary.
B2 55-110 cm	Very dark gray to dark brown (7.5YR3/1) moist, clay; moderate medium angular blocky; sticky plastic wet, firm moist; common fine pores; few fine roots; abrupt and smooth boundary.
C > 110 cm	Highly weathered rock.

FIELD NO: K11

PROJECT: Kulumsa Research Center

LOCATION: Block No. 120

ALTITUDE: 2120 m

COORDINATES: N 8°00'55" E 39°09'43"

AUTHOR (S): Kebede A. and Gebeyehu B.

SOIL CLASSIFICATION: Vertic Cambisols

SURROUNDING LANDFORM: strongly sloping plateau

PHYSIOGRAPHIC POSITION: Lower slope

LAND USE/COVER: wheat field

SLOPE GRADIENT: 11%

MOISTURE CONDITION: dry 0- 57 cm, moist below

DRAINAGE CLASS: well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Pyroclastic

EROSION STATUS: None

CLIMATE: Tepid to cool sub-moist

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0 - 25 cm	Very dark brown (10YR2/2) moist and very dark grayish brown (10YR3/2) dry, clay; strong coarse sub angular blocky; fine to medium very closely spaced cracks; sticky plastic wet, friable moist, hard dry; common fine interstitial pores; many fine roots; clear and smooth boundary.
A25-57 cm	Very dark brown (10YR2/2) moist and Very dark brown (10YR2/2) dry; clay; strong medium sub angular blocky; sticky plastic wet, friable moist, hard dry; few fine interstitial pores; common fine roots; gradual and smooth boundary.
Bt 57-95 cm	Black (10YR2/1) moist, clay; strong coarse angular blocky; very sticky very plastic wet, firm moist; common distinct clay cutans; very few fine interstitial pores; few fine roots; clear and smooth boundary.
Bt2 95-120 cm	Brown to dark brown (7.5YR3/4) moist; moderate medium angular blocky; sticky plastic wet; friable moist; few distinct pressure faces; very few fine interstitial pores; clear and smooth boundary.
C >120cm	Highly weathered rock.

FIELD NO: K12

PROJECT: Kulumsa Research Center

LOCATION: Block No. 120

ALTITUDE: 2120 m

COORDINATES: N 8°01'51" E 39°07'51"

AUTHOR (S): Kebede A. and Gebeyehu B.

SOIL CLASSIFICATION: Vertic Luvisols

SURROUNDING LANDFORM: sloping plateau

PHYSIOGRAPHIC POSITION: Lower slope

LAND USE/COVER: wheat field

SLOPE GRADIENT: 8%

MOISTURE CONDITION: dry 0- 18 cm, moist blow

DRAINAGE CLASS: well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Pyroclastic

EROSION STATUS: None

CLIMATE: Tepid to cool sub-moist

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0 - 18 cm	Reddish brown (5YR3/2) moist and dark reddish brown (5YR3/4) dry, clay; moderate coarse sub angular blocky; fine very closely spaced cracks; sticky plastic wet, friable moist, hard dry; common fine interstitial pores; many very fine roots; clear and smooth boundary.
AB 18-45 cm	Dark reddish brown (2.5YR2.5/4) moist, clay; moderate coarse sub angular blocky; sticky plastic wet, friable moist; common fine interstitial pores; common Mg nodules; few fine roots; gradual and smooth boundary.
Bt 45-90 cm	Very dark brown (7.5YR2/2) moist, clay; moderate medium angular blocky; very sticky very plastic wet, friable moist; common distinct clay cutans; very few fine interstitial pores; few CaCO ₃ ; few fine roots; clear and smooth boundary.
BC 90-110+ cm	Brown to dark brown (7.5YR3/4) moist; clay; sticky plastic wet; friable moist; calcareous.

FIELD NO: K13

PROJECT: Kulumsa Research Center

LOCATION: Block No. 40

ALTITUDE: 2190 m

COORDINATES: N 8°01'24" E 39° 09'26"

AUTHOR (S): Kebede A. and Gebeyehu B.

SOIL CLASSIFICATION: Vertic Cambisols

SURROUNDING LANDFORM: gently sloping plateau

PHYSIOGRAPHIC POSITION: mid slope

LAND USE/COVER: rap seed field

SLOPE GRADIENT: <5%

MOISTURE CONDITION: 0- 80 cm dry moist blow

DRAINAGE CLASS: well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Pyroclastic

EROSION STATUS: None

CLIMATE: Tepid to cool sub-moist

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0 - 23 cm	Dark reddish brown (5R3/2) moist and dusky red (2.5YR3/2) dry, clay; strong coarse angular blocky; fine very closely spaced cracks; slightly sticky slightly plastic wet, friable moist, hard dry; common fine interstitial pores; many fine roots; gradual and smooth boundary.
B1 23-80cm	Dark reddish brown (5YR2.5/2) moist and dark reddish brown (5R3/2) dry; clay; strong coarse angular blocky; sticky plastic wet, friable moist; hard dry; common distinct clay cutans; few fine interstitial pores; common fine roots; gradual and smooth boundary.
B2 80-95/100 cm	Dark reddish brown (5YR3/3) moist, clay; moderate coarse angular blocky; sticky plastic wet, friable moist; common distinct clay cutans; fine roots; clear and wavy boundary.
C >95/100 cm	Highly weathered rock.

LAND FIELD NO: K14

PROJECT: Kulumsa Research Center

LOCATION: Block No. 80

ALTITUDE: 2190 m

COORDINATES: N 8°01'18" E 39°08'34"

AUTHOR (S): Kebede A. and Gebeyehu B.

SOIL CLASSIFICATION: Vertic Luvisols

SURROUNDING LANDFORM: flat plateau

PHYSIOGRAPHIC POSITION: intermediate part

LAND USE/COVER: wheat field

SLOPE GRADIENT: 1.5%

MOISTURE CONDITION: 0-20 cm dry moist blow

DRAINAGE CLASS: well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Pyroclastic

EROSION STATUS: None

CLIMATE: Tepid to cool sub-moist

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0 - 20 cm	Very dark reddish brown (7.5YR2.5/2) moist and dark brown (7.5YR3/3) dry, clay; strong coarse sub angular blocky; fine moderately widely spaced cracks; sticky plastic wet, friable moist, hard dry; many fine interstitial pores; many fine roots; clear and smooth boundary.
AB 20-60cm	Dark reddish brown (5YR3/2) moist, clay; moderate medium angular blocky; sticky plastic wet, friable moist hard dry; common fine interstitial pores; common fine roots; gradual and smooth boundary.
Bt1 60-100 cm	Very dark brown (10YR2/2) moist, clay; moderate coarse angular blocky; very sticky very plastic wet, friable moist; common distinct pressure faces; few fine roots; clear and smooth boundary.
Bt1100-127cm	Dark brown (7.5YR3/2) moist, clay; moderate medium angular blocky; very sticky very plastic wet, friable moist; common distinct pressure faces; very few fine interstitial pores clear and wavy boundary.
C>127cm	Highly weathered rock.

LAND FIELD NO: K15

PROJECT: Kulumsa Research Center

LOCATION: Block No. 120

ALTITUDE: 2190 m

COORDINATES: N 8°00'53" E 39°09'04"

AUTHOR (S): Kebede A. and Gebeyehu B.

SOIL CLASSIFICATION: Vertic Luvisols

SURROUNDING LANDFORM: sloping plateau

PHYSIOGRAPHIC POSITION: mid slope

LANUSE/COVER: wheat field

SLOPE GRADIENT: 7%

MOISTURE CONDITION: 0-20 cm dry moist below

DRAINAGE CLASS: well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Pyroclastic

EROSION STATUS: None

CLIMATE: Tepid to cool sub-moist

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0 - 20 cm	Very dark reddish brown (5YR3/2) moist and dark brown (7.5YR3/2) dry, clay loam; strong coarse sub angular blocky; fine widely spaced cracks; slightly sticky slightly plastic wet, firm moist, hard dry; many fine interstitial pores; many fine roots; gradual and smooth boundary.
Bt 20-63cm	Dark reddish brown (5YR3/2) moist, clay; moderate medium angular blocky; sticky plastic wet, friable moist; common distinct slickensides; common fine interstitial pores; few fine roots.
C>63 cm	Highly weathered rock.

Annex 2. Climatic data

a) Mean monthly rainfall (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1979	20.0	68.7	207.6	55.0	122.4	56.9	124.9	138.9	104.0	29.6	0.0	15.0	943.0
1980	13.0	5.5	56.8	38.8	66.9	99.0	130.0	85.9	70.7	26.9	0.0	0.0	593.5
1981	0.0	28.6	206.7	94.5	16.1	11.9	164.0	98.1	107.0	20.4	0.0	0.2	747.5
1982	29.4	58.3	23.3	95.1	107.7	70.6	142.1	167.2	96.9	84.3	14.7	36.4	926.0
1983	5.6	16.0	128.4	99.3	239.4	64.8	161.7	188.6	104.9	12.5	4.3	0.0	1025.5
1984	0.0	0.0	9.5	0.0	151.0	84.1	79.9	155.0	122.9	10.6	0.0	17.0	630.0
1985	8.6	8.8	15.3	84.7	56.5	57.7	134.6	95.8	108.0	25.5	1.2	1.0	597.7
1986	0.0	156.5	84.5	123.5	81.2	115.2	107.9	72.6	120.0	48.7	11.7	16.2	938.0
1987	2.2	21.6	108.8	150.6	157.8	49.4	59.6	116.0	88.2	5.8	3.1	11.7	774.8
1988	64.2	79.3	25.0	113.6	60.4	82.7	133.9	122.8	136.4	56.3	0.0	0.0	874.6
1989	0.2	49.8	69.9	177.9	25.0	132.4	115.9	180.0	96.8	31.6	5.0	41.2	925.7
1990	0.0	160.6	100.6	155.2	30.5	97.1	180.8	109.8	120.3	22.7	5.5	0.9	984.0
1991	10.4	42.7	185.3	11.1	92.8	67.5	168.4	123.7	86.3	10.8	0.0	12.1	811.1
1992	25.5	96.0	4.5	65.6	28.8	68.0	109.1	174.1	104.6	81.5	36.1	14.5	808.3
1993	20.5	72.0	12.9	148.0	152.5	49.0	112.4	145.1	128.1	59.0	0.0	30.8	930.3
1994	0.0	13.0	34.5	66.7	42.8	161.3	121.1	133.6	105.6	1.1	32.9	15.4	728.0
1995	0.0	34.0	158.5	140.3	64.8	79.3	120.0	142.1	74.3	2.2	0.0	45.8	861.3
1996	42.0	4.3	133.3	58.9	192.9	126.5	130.3	98.5	81.5	1.3	3.5	0.0	873.0
1997	6.4	0.0	218.2	112.7	31.0	115.5	138.1	108.6	61.2	93.5	26.7	0.0	911.9
1998	27.6	19.8	52.0	69.1	91.7	24.9	21.3	20.8	20.7	23.9	26.1	0.0	397.9
1999	23.0	23.1	24.1	25.9	25.3	23.5	18.0	20.7	20.1	20.7	21.1	21.5	267.0
Mean	14.2	45.6	88.6	89.8	87.5	78.0	117.8	118.9	93.3	31.9	9.1	13.3	788.1

b) Mean monthly pan evaporation (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1979	141	160	187	223	188	147	120	89	84	182	244	205	1970
1980	217	181	212	223	374	129	110	118	113	278	321	191	2467
1981	364	272	141	155	303	219	137	128	103	252	299	285	2658
1982	206	130	291	191	248	207	149	126	116	189	174	183	2210
1983	268	170	161	150	153	156	156	120	110	220	239	251	2154
1984	260	325	359	397	208	168	170	130	147	330	201	218	2913
1985	254	290	279	203	238	269	172	122	117	257	281	297	2779
1986	328	185	265	155	235	138	150	195	142	297	288	260	2638
1987	277	248	177	221	176	161	182	148	101	208	213	294	2406
1988	183	148	262	147	209	137	112	98	91	164	213	1941	3705
1989	199	167	173	108	219	158	128	118	116	228	212	131	1957
1990	205	89	145	164	159	163	113	104	94	231	196	237	1900
1991	214	150	143	220	221	156	105	101	116	194	209	198	2027
1992	140	118	205	187	213	146	108	100	99	138	150	66	1670
1993	141	126	240	131	148	121	119	114	101	126	185	195	1747
1994	216	191	175	221	161	88	59	94	116	226	163	178	1888
1995	184	157	148	92	155	154	111	123	115	220	229	146	1834
1996	109	240	293	148	138	120	102	94	60	201	107	158	1770
1997	198	239	206	157	176	73	140	41	105	146	90	168	1739
1998	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	51	147	241	287	726
1999	247	271	161	218	251	132	54	97	73	Nr	Nr	Nr	1504
Mean	218	193	211	186	209	152	125	113	103	212	213	294	2233

c) Note: Nr = No record

c) Mean monthly maximum temperature (°C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1979	26.3	27.7	28.4	28.5	26.1	24.6	22.3	21.4	22.2	25.3	26.3	26.2	25.4
1980	26.3	27.6	Nr	Nr	Nr	Nr	Nr	Nr	22.4	23.6	19.2	24.3	23.9
1981	25.5	25.6	23.5	22.8	26	26.4	21.9	21.5	21	23.2	23.5	23.4	23.7
1982	23.9	24.5	26.3	24.7	24.9	25.7	22.4	20.8	21.5	21.1	21.8	22.9	23.4
1983	22.6	24.1	25	24.4	24.5	24	22.9	21.5	21.1	22.3	23	23.2	23.2
1984	23.1	24.4	26.7	28.1	24.5	23	21.9	21.6	22.3	24.9	23.7	22.8	23.9
1985	24.9	25	27	23.7	24.4	25	21	20.6	21.3	23.4	24.2	23.9	23.7
1986	23.9	24.3	25.4	23.8	24.9	21.5	20.9	21.7	21.1	23.2	24	23.1	23.2
1987	23.1	25	23.9	23.8	23.2	22.9	22.9	21.4	22.4	24.1	24.1	24	23.4
1988	23.3	23.6	26.1	24.9	25	23.2	20.4	20.3	20.6	21.7	22.2	21.9	22.8
1989	22	20.9	24.2	21.8	24.2	22.9	20.5	20.3	20.3	22	22	21.5	21.9
1990	22.5	22.1	22	22.9	24.6	23.7	20.7	20	20.4	22.2	22.7	20.8	22.1
1991	23.7	23.7	23.6	24.3	25	24.5	19.9	20.1	21.9	22.6	22.6	21.9	22.8
1992	21.6	21.4	25.6	25.4	25.5	24	20.6	19.9	20.5	21.4	21.4	21.4	22.4
1993	21.6	20.7	25.3	23.3	22.9	22.2	20.7	20.6	20	21.6	22.8	22.3	22.0
1994	23.4	25	25.1	21.9	25.1	22.9	19.2	Nr	Nr	Nr	Nr	Nr	23.2
1995	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	22.1	22.8
1996	21.8	24.5	24.1	23.6	22.9	21.3	21.2	20.4	21	22.6	22.4	22.3	22.3
1997	25.9	23	25.1	22.9	24.6	23.2	21.3	21.1	22.5	21.4	21.3	21.7	22.8
1998	22	23.9	24.9	26	24.9	24.2	21.3	20.8	20.7	23.9	21.5	21.5	23.0
1999	23	23.1	24.1	25.9	25.3	23.5	18	20.7	20.1	20.7	21.1	21.5	22.3
Mean	23.5	24.01	25.07	24.35	24.66	23.62	21.05	20.82	21.23	22.7	22.6	22.7	23.0

d) Mean monthly minimum temperature (°C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1979	9.4	9.7	11	11.8	12.1	11.7	11.2	11.1	11	10.8	8.6	8.6	10.6
1980	8.4	9.8	11.6	12.7	12.4	11.8	11.2	11	10.5	10.2	8.9	7	10.5
1981	7.6	9.1	11.3	11.9	11.9	10.4	10.9	10.7	9.9	10.7	6.8	9.9	10.1
1982	7.9	9.4	9.9	10.8	11.5	10.2	10	10.3	9.5	9.7	9.9	7.9	9.8
1983	6.8	9.2	10.9	11.2	11.4	10.4	10.9	9.8	8.3	8.6	7.9	7.8	9.4
1984	6.7	6.5	9.4	12	11.6	10.4	10.2	10.4	9.8	8.8	7.8	6.8	9.2
1985	7	8.6	9.6	11.3	10.5	10	10	9.7	9.6	9	8.2	7	9.2
1986	6.7	9.7	10	11.2	10.8	10.4	9.9	9.7	9.4	9.9	8.4	7.6	9.5
1987	7.4	8.9	10.8	13.6	11.4	10.4	10.3	10.2	11.1	11.2	9.5	8.8	10.3
1988	9.1	10.5	11.7	12	10.9	11	11.6	11	10.6	10.5	7.6	7.6	10.3
1989	7.7	8.6	10.4	11.4	11.1	11.4	11.8	11.3	11.3	11.4	10.5	10.3	10.6
1990	9	12.2	11.3	12.5	12.3	11.5	11.9	11.8	11.6	12.1	9.2	8.7	11.2
1991	9.9	11.3	12	13	13.6	12.5	12.1	11.8	11.2	11.4	8.7	9.6	11.4
1992	10.2	11.4	11.9	12.7	12.6	12.1	11.9	12.1	10	11.6	9.3	10.5	11.4
1993	10.3	10.2	10.5	12.6	12.4	11.7	11.9	11.2	11.2	11.2	10.1	8	10.9
1994	8.1	10.3	12.9	13.2	12.3	12	11.7	Nr	Nr	Nr	Nr	Nr	11.5
1995	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	8.9	8.9
1996	10.3	9.8	11.2	12.3	12.4	11.8	12	11.7	11.1	10.9	9.2	8.2	10.9
1997	10.1	9.2	11.2	11.8	12.3	11.2	11.4	11.1	10.7	11.8	10.2	9.1	10.8
1998	9.3	10.1	11.4	11.8	11.3	11.3	10.9	10.7	10.2	11.6	8.2	2.3	9.9
1999	8	7.8	12	12.7	12.3	12.2	11.9	11.8	11.4	11.6	11.1	9.1	11.0
Mean	8.5	9.6	11.1	12.1	11.9	11.2	11.2	10.9	10.4	10.7	9.0	8.2	10.4

Annex 3. Analytical data of the soils

Mapping Unit	Pedon No.	Depth (cm)	Texture %				pH, H ₂ O	EC, 1:2.5 mS/cm	C %	N %	C/N	Exchangeable cations (cmol(+)/kg soil)					BSP	ESP	Av. P ppm	Micronutrients (ppm)			
			Sand	Silt	Clay	Class						Na	K	Ca	Mg	CEC				Fe	Mn	Zn	Cu
2b2	K1	0-30	19	40	41	C	6.0	0.03	0.20	2.95	15	0.84	3.11	21.8	4.8	33.4	91	2.5	11.5	47.5	74.0	1.7	1.9
		30-100	15	22	63	C	6.9	0.05	0.08	0.88	10	1.01	2.49	31.3	6.2	38.6	100	2.6	0.9	12.4	20.7	0.2	1.4
		100-125	17	24	59	C	7.8	0.05	0.04	0.48	11	1.18	2.26	31.2	5.6	39.6	100	3.0	0.9	8.8	11.3	0.2	1.0
		125-150	29	44	27	L	8.3	0.08	0.04	0.30	8	2.53	3.35	35.7	6.3	42.8	100	5.9	1.2	8.5	3.3	0.7	0.5
3b2	K2	0-25	23	34	43	C	6.1	0.02	0.15	2.07	13	0.76	2.09	23.4	6.1	36.4	89	2.1	8.1	22.2	49.8	0.6	1.4
		25-80	17	22	61	C	6.4	0.02	0.10	1.30	13	0.84	1.67	25.0	5.7	38.6	86	2.2	1.1	9.9	13.3	1.1	1.2
		80-110	15	18	67	C	7.4	0.02	0.04	0.54	13	0.84	1.69	28.3	5.8	39.2	93	2.1	0.7	8.4	12.1	0.1	0.9
		110-140	41	42	17	L	8.4	0.08	0.04	0.28	7	1.60	2.06	41.3	6.6	40.8	100	3.9	0.8	9.3	0.2	0.7	0.3
3b2	K3	0-30	19	36	45	C	6.5	0.03	0.18	2.33	13	0.84	3.05	22.0	5.8	35.0	91	2.4	13.2	28.5	55.4	1.0	1.8
		30-95	17	22	61	C	7.2	0.04	0.08	1.20	14	1.26	1.87	25.7	7.1	43.0	84	2.9	1.4	14.8	16.7	0.1	1.2
		95-135	15	26	59	C	8.4	0.08	0.07	0.48	7	2.70	2.58	32.6	7.5	42.2	100	6.4	0.6	6.4	2.9	0.1	1.0
		135-160	37	46	17	L	8.4	0.22	0.03	0.24	9	2.95	2.45	38.1	7.9	44.0	100	6.7	0.9	7.6	0.0	0.7	0.3
2b2	K4	0-25	21	36	43	C	6.8	0.04	0.17	2.17	13	0.84	2.85	20.7	5.3	43.4	68	1.9	8.9	33.3	60.6	0.9	1.8
		25-100	17	24	59	C	7.5	0.03	0.08	1.00	12	1.43	2.03	31.6	6.3	41.4	100	3.5	0.6	9.4	12.0	0.1	1.4
		100-135	17	22	61	C	7.1	0.06	0.06	0.96	17	1.01	1.87	27.5	6.2	38.4	95	2.6	4.4	20.1	24.8	0.3	1.4
		135-175	41	32	27	L	8.2	0.16	0.04	0.36	9	1.51	2.32	37.8	6.5	41.0	100	3.7	1.0	8.5	0.2	0.6	0.5
2b2	K5	0-25	21	38	41	C	5.9	0.05	0.18	2.49	14	0.67	2.03	24.9	4.8	31.4	100	2.1	6.8	35.7	65.7	1.2	1.7
		25-45	23	32	45	C	6.4	0.04	0.11	1.98	18	0.50	1.41	18.9	4.7	32.6	78	1.5	5.0	36.4	57.4	0.7	1.8
		45-70	23	24	53	C	6.4	0.04	0.10	1.30	13	0.84	1.38	22.9	5.8	37.4	83	2.2	3.2	12.0	8.8	0.1	1.1
		70-115	15	24	61	C	7.0	0.02	0.06	0.94	15	1.01	1.56	26.9	5.8	39.0	91	2.6	1.0	11.6	13.7	0.1	1.1
		115-145	15	24	61	C	7.4	0.03	0.06	0.56	10	1.26	1.69	29.9	6.3	39.2	100	3.2	0.5	7.9	10.9	0.1	1.3
		145-185	25	40	35	CL	7.8	0.05	0.01	0.14	10	2.19	2.19	32.9	6.6	46.6	94	4.7	0.5	6.9	0.0	0.2	0.4
2a1	K6	0-30	17	38	45	C	6.1	0.02	0.18	2.69	15	0.84	1.97	25.9	6.8	40.4	88	2.1	7.5	50.9	55.3	0.9	1.9
		30-75	15	24	61	C	7.5	0.04	0.08	1.32	16	1.85	1.77	37.8	8.9	48.0	100	3.9	1.3	16.1	3.2	0.1	1.3
		75-150	12	20	68	C	8.3	0.08	0.06	0.76	14	3.12	1.93	42.5	8.9	50.0	100	6.2	1.7	6.3	0.0	0.1	1.5
		150-200	14	24	62	C	8.6	0.10	0.04	0.56	13	2.62	1.97	43.6	7.7	46.8	100	5.6	6.8	4.9	0.0	0.0	1.3
3b6	K7	0-25	20	40	40	CL	6.1	0.06	0.18	2.51	14	0.76	2.95	19.8	4.9	34.4	83	2.2	7.2	43.1	73.7	0.8	1.9
		25-50	18	30	52	C	6.4	0.03	0.17	2.00	12	0.76	1.90	25.3	5.4	38.2	87	2.0	1.5	33.1	36.7	0.4	1.7
		50-90	12	38	50	C	6.6	0.03	0.07	0.80	11	1.09	1.85	29.4	5.5	41.6	91	2.6	0.4	7.6	12.8	0.2	1.5
		90-110	18	32	50	C	8.2	0.04	0.04	0.44	10	1.26	1.56	30.2	5.3	39.6	97	3.2	1.0	5.7	3.8	0.2	1.0
		>110	22	44	34	CL	8.3	0.04	0.01	0.14	10	2.28	1.99	27.1	4.7	36.8	98	6.2	0.3	5.7	0.0	0.3	0.5
2b1	K8	0-30	18	42	40	C	6.4	0.06	0.18	2.21	12	1.19	3.61	21.1	5.8	34.8	91	3.4	11.7	47.9	70.3	1.0	2.3
		30-90	12	22	66	C	7.4	0.03	0.11	1.10	10	2.54	3.04	33.9	8.3	45.8	100	5.5	0.7	17.8	12.8	0.4	1.8
		90-110	14	28	58	C	8.4	0.05	0.06	0.60	11	3.13	2.89	35.7	8.9	46.8	100	6.7	0.5	5.7	0.0	0.1	1.7
		120-140	12	28	60	C	8.4	0.18	0.04	0.42	10	3.12	2.33	40.5	7.8	47.6	100	6.6	0.0	4.9	0.0	0.1	1.6
		140+	28	30	42	C	8.4	0.19	0.03	0.30	11	2.62	1.59	33.0	5.6	37.4	100	7.0	0.5	4.7	0.0	0.6	1.1
1b2	K9	0-30	18	40	42	C	6.3	0.07	0.15	2.09	14	1.27	4.17	19.7	5.5	33.8	91	3.8	8.1	38.2	59.8	1.2	1.9
		30-85	20	26	54	C	7.1	0.02	0.07	1.18	17	1.52	3.04	31.3	7.3	44.2	98	3.4	0.3	17.2	15.9	0.3	1.3
		85-140	12	22	66	C	7.7	0.02	0.04	0.52	12	1.77	2.32	33.1	6.8	44.6	98	4.0	0.2	7.9	3.8	0.2	1.4
		140-165+	30	42	28	CL	8.4	0.13	0.01	0.12	9	1.43	1.92	29.9	4.8	30.4	100	4.7	0.3			0.2	0.6

Mapping Unit	Pedon No.	Depth (cm)	Texture %				pH, H ₂ O 1:2.5	EC, 1:2.5 mS/cm	C %	N %	C/N	Exchangeable cations (cmol(+)/kg soil)					BSP	ESP	Av. P ppm	Micronutrients (ppm)			
			Sand	Silt	Clay	Class						Na	K	Ca	Mg	CEC				Fe	Mn	Zn	Cu
4b2	K10	0-20	34	26	40	C	6.3	0.07	2.67	0.20	14	0.4	1.77	21.8	5.6	39.5	75	1.0	1.6	40.8	62.08	0.54	1.26
		20-55	28	30	42	C	6.8	0.07	1.83	0.11	16	0.64	1.43	25.3	5.3	37.5	87	1.7	0.2	26.9	54.96	0.72	1.08
		55-110	80	8	12	SL	7.4	0.08	1.36	0.08	16	1.12	2.00	24.4	4.9	42.5	76	2.6	trace	13.1	23.18	0.16	0.96
		110-130	26	26	48	C	7.7	0.12	0.42	0.06	7	1.84	2.21	30.9	5.9	43.0	95	4.3	"	11.7	9.80	0.76	0.14
4b2	K11	0-25	16	30	54	C	6.8	0.15	2.79	0.19	15	0.32	3.98	21.8	3.7	33.5	89	1.0	56.0	11.9	60.62	2.66	1.70
		25-57	26	28	46	C	7.2	0.11	1.71	0.13	13	0.24	4.81	25.5	5.8	37.1	98	0.6	8.0	21.7	23.72	0.62	1.48
		57-95	74	6	20	SCL	7.2	0.13	1.14	0.08	15	0.48	2.29	26.2	5.5	37.1	93	1.3	1.2	17.6	17.48	0.52	1.30
		95-120	20	26	54	C	7.6	0.12	0.52	0.06	9	0.48	2.03	27.1	5.2	37.8	92	1.3	0.8	11.0	20.58	0.36	0.88
		120-130	28	36	36	CL	7.7	0.12	0.20	0.02	10	0.56	1.77	26.2	4.7	37.5	89	1.5	1.0	10.0	11.50	0.44	0.36
3c2	K12	0-18	26	24	50	C	6.1	0.09	2.26	0.16	14	0.56	1.63	21.4	5.8	30.7	96	1.8	trace	32.1	71.88	0.6	1.12
		18-45	26	20	54	C	6.6	0.05	1.24	0.10	13	0.80	0.83	21.1	8.3	41.5	75	1.9	"	11.8	12.02	0.16	0.88
		45-90	16	20	64	C	7.9	0.08	0.72	0.06	13	1.84	0.55	21.4	10.8	42.5	81	4.3	"	7.8	7.82	0.64	0.56
		90-110	28	18	54	C	8.8	0.20	0.32	0.04	9	0.40	1.48	22.2	10.3	33.0	104	1.2	"	7.5	5.04	0.48	0.48
2c2	K13	0-23	16	34	50	C	6.6	0.04	2.08	0.15	13	0.40	2.13	18.8	5.8	38.4	70	1.0	3.8	39.5	70.42	0.88	1.76
		23-80	20	24	56	C	7.3	0.03	1.18	0.10	12	0.56	2.33	16.3	5.2	36.0	68	1.6	0.4	18.3	38.88	0.98	1.36
		80-100	20	34	46	C	8.1	0.06	0.72	0.07	10	0.80	2.80	21.1	5.8	34.6	88	2.3	0.6	5.3	13.18	0.34	1.14
		100-125	36	36	28	CL	8.6	0.15	0.42	0.06	7	0.80	3.20	26.3	5.8	32.8	110	2.4	0.8	4.8	5.84	0.24	0.56
1b2	K14	0-20	26	32	42	C	6.3	0.04	1.60	0.15	10	0.32	1.55	15.1	4.5	31.7	68	1.0	9.4	52.6	135.08	1.14	2.04
		20-60	28	28	44	C	6.3	0.06	1.50	0.13	12	0.80	1.23	17.8	5.3	40.7	62	2.0	0.4	36.7	36.00	0.26	1.68
		60-100	36	4	60	C	7.4	0.03	0.98	0.09	11	0.88	1.63	21.5	5.9	39.3	76	2.2	trace	15.5	12.58	0.28	1.08
		100-127	28	20	52	C	8.0	0.05	0.65	0.06	12	0.88	1.90	25.7	5.9	40.5	85	2.2	"	9.3	13.40	0.76	1.36
		127-135	34	34	32	CL	8.4	0.13	0.50	0.04	12	0.88	1.20	17.8	3.8	28.9	82	3.0	0.4	6.5	13.58	0.18	0.48
3c6	K15	0-20	28	38	34	CL	6.4	0.06	2.49	0.20	13	0.32	1.60	17.0	5.3	36.0	67	0.9	11.6	53.2	90.26	1.12	1.64
		20-63	36	4	60	C	7.0	0.04	0.98	0.10	10	0.48	3.00	17.8	5.7	41.8	64	1.1	0.8	23.2	36.66	0.66	0.72
		63-75	20	60	20	SiL	7.6	0.05	0.40	0.04	11	0.04	4.00	16.9	5.3	34.8	75	0.1	0.8	15.9	11.82	1.82	0.32