

SOILS OF SINANA AGRICULTURAL RESEARCH CENTER

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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 Characterization and Evaluation Program, which is coordinated and largely implemented by the National Soil Research Center (NSRC). The main activity under this program is soil survey and land evaluation research project.

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 for Kulumsa, Areka and Pawe Agricultural Research Centers.

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 research center. The survey report has 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.

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ABSTRACT

Soils of the Sinana Agricultural Research Center, located in Bale Zone of the Oromia Region at about 460 km southeast of Addis Ababa, were surveyed by fixed-grid technique at 100 by 50 m intensity (1:5,000 scale). The total area of the center is about 276.55ha. Eleven soil-mapping units were identified on the basis of surface slope, soil depth and surface soil texture. For detail characterization and classification of the soils in the mapping units 15 pedons were described and sampled by horizon for laboratory analyses.

The major soil types identified in the center are Phaeozems, Cambisols with minor occurrence of Vertisols. The soils are deep, fine textured and have aggregated soil structure with good porosity. The soils have slightly acidic to strongly acidic reaction and are not saline and sodic. The organic matter and total nitrogen content decrease with depth. The cation exchange capacity of the soils varies from 23 to 58 cmolc kg⁻¹ soil and the base saturation percentage is between 51 and 99%. The available K content of the soils relative to Ca and Mg is high and this may affect Ca and Mg availability. The available phosphorous, zinc and copper content of the soils is low. Thus future soil fertility works should focus on the status and availability of macro- and micronutrients in the soils.

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1. INTRODUCTION

Research and extension in the agricultural sector has begun long ago 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 a very generalized and approximation of recommendation. Amongst is the difficulty in dissemination and extrapolation of research findings and outputs to other areas due to lack of sufficient soil information.

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 area 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 testing sites have not been done. Therefore, this study was undertaken for detail characterization of the soils at Sinana Agricultural Research Center (SARC).

The SARC is located in the Oromia National Regional State, Ethiopia. This report presents the characteristics of the soils of the SARC.

2. DESCRIPTION OF THE AREA

2.1 Location and Access

Sinana Agricultural Research Center (SARC) is located in Oromiya Regional State, Bale Administrative Zone. It is at about 460 Km southeast of Addis Ababa and it has an altitude of 2400 m above sea level. Its geographical extent ranges from 07° 06'12" to 07° 07'29" northern latitude and from 40° 12'40" to 40° 13'52" eastern longitude. It has a total area of 276.55 ha.

2.2 Climate

According to the records from 1990 to 2001 (Annex 2.), the mean annual rainfall at Sinana is 812 mm. It has a bimodal rainfall pattern with the first peak from April to May and the second from August to October. The mean annual maximum temperature is 21.060C and monthly values range between 19.390C in October and 22.940C in February. The mean annual minimum temperature is 9.320C and monthly values range between 7.120C in December and 10.810C in April. The coldest month is December whereas February is the hottest month.

2.3 Geology

According to Tefera et al. (1996) the geology of the Sinana area consists of flood basalt belonging to the Arsi and Bale Basalts of the Oligocene - Miocene volcanic eruptions and rhyolite belonging to the Ghinir Formation of the Quaternary volcanic eruptions. Highly calcareous material was observed underlying most soil profiles.

3. SURVEY METHODS

3.1 Office Work

Prior to commencement of the field soil investigation, a reconnaissance field visit has been conducted to map the overall layout and different attributes of the center. 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 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 field soil investigation was conducted in two successive steps:

Auger observation: After having the preliminary site and photo interpretation maps 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 100 m by 50 m. In some irregular units additional observations were made to study the variability. Baselines of the grid system were oriented in such a way that observation traverses cut-across soil boundaries. In total 182 auger observations were made.

Profile sampling: For further soil characterization, soil profile pits were dug on fifteen representative sites. The soil profile descriptions made according to FAO (1990) guidelines for soil profile description. Soil samples were collected from the flat face of each natural soil

horizons.

3.3 The Soil Map and Legend

Mapping units (Figure 1) were 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 land units of the farm. Land with uniform slope and soil depth was further subdivided on the basis of surface texture. Thus, the mapping unit of the farm indicates areas that are uniform in slope, soil depth and surface texture (Table 1). A total of eleven different mapping units have been identified (Table 2).

Table 1 Distinguishing criteria of the mapping units.

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

Each mapping 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). For example: 1b2: wherein, 1-slope class, b-depth class and 2-surface texture.

Table 2 List of mapping units identified in the Sinana ARC.

Mapping Unit	Pedon No	Slope (%)	Soil depth (Cm)	Texture (0 - 30 cm)	Area		Soil Units (WRB, 1998)
					ha	%	
1b2	S5	0-1	100-150	Clay	37.25	13.47	HAPLIC PHAEOZEMS
2a2	S6 & S10	1-2	>150	Clay	8.95	3.24	Haplic Phaeozems
3a1	S14	2-5	>150	Heavy Clay	4.37	1.58	Vertic Cambisols
3a2	S7, S8 & S11	2-5	>150	Clay	40.41	14.61	Haplic Cambisols
3a2*	S9	2-5	>150	Clay	14.68	5.31	Haplic Phaeozems
3b2	S1	2-5	100 -150	Clay	30.72	11.11	Luvic Phaeozems
3b2*	S3	2-5	100 -150	Clay	38.30	13.85	Haplic Phaeozems
3b5	S2	2-5	100 -150	Clay Loam	5.50	1.99	Luvic Phaeozems
4a1	S12	5-10	>150	Heavy Clay	7.63	2.76	Vertic Cambisols
4c1	S15	5-10	50-100	Heavy Clay	7.96	2.88	Eutric Vertisols
4c2	S4 & S13	5-10	50 - 100	Clay	12.10	4.37	Luvic Phaeozems
Other Features							
GL	-	-	-	-	40.24	14.55	Grass land
RC	-	-	-	-	8.82	3.19	Shallow/Stony/Rocky
Gr	-	-	-	-	0.91	0.33	Garage
Compound	-	-	-	-	18.76	6.78	Compound
Total					276.60	100	

3.4 Laboratory Analyses

The soil samples were air-dried and ground to pass through a 2-mm sieve before analysis. Soil analysis was carried out as outlined in Van Reeuwijk (1993) unless otherwise specified. Soil texture was determined by the modified Bouyoucos hydrometer method and the pH of the soils was potentiometrically measured by water (pHH₂O) in the supernatant suspension of soil to solution ratio of 1:2.5. Organic carbon content of the soil was determined by the wet combustion procedure of Walkley and Black as outlined by Van Ranst et al. (1999). Total nitrogen content of the soil was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). The available phosphorus content of the soils was determined by 0.5 M sodium bicarbonate extraction solution (pH 8.5) method of Olsen. Exchangeable cations content and the cation exchange capacity (CEC) of the soils were determined by the 1 M ammonium acetate (pH 7) method according to the percolation tube procedure. The available micronutrients content of the soils (Fe, Mn, Zn, and Cu) was determined by diethylenetriaminepentaacetic acid (DTPA) method (Tan, 1996).

4 RESULTS AND DISCUSSION

4.1 Physico-chemical Characteristics of the Mapping Units

The physico-chemical characteristics of the mapping units are given in the subsequent sections. The distribution of the different soil units in the research center is shown in figure 2 and the major physico-chemical properties of each unit are given in Table 3. Detailed analytical data of the soil profiles are given in Annex 3.

4.1.1 Mapping Unit: 1b2

This unit refers to well-drained soil that occurs on a nearly level land (0 to 1% slope). It covers 37.25ha or 13.47% of the farm.

Soils of the unit are deep (100-150 cm) and have a color of very dark gray (7.5YR3/1) when moist. The texture is clay with strong medium sub angular blocky structure. These soils have consistency that is friable when moist and sticky plastic when wet.

The pH of surface soil is 6.5 (slightly acidic), increasing to 7.3 (moderately alkaline) in subsurface horizons. The electrical conductivity is generally non-saline that ranges between 0.005 and 0.011 ds/m. The cation exchange capacity of the soils is very high (46.8 to 50.6 cmol (+)/kg soil and it is high base saturated (69 to 78%). The organic matter content is low to medium (1.045 to 2.6849%) and total nitrogen is very high (0.38 to 5.56%); while available phosphorous is low to medium (1.6 to 9.96 ppm). Available micronutrients range between 6.92 to 20.5 ppm for Fe, 5.12 to 37.22 ppm for Mn, 0.1 to 0.66 ppm for Zn and 1.5 to 2.24 ppm for Cu.

4.1.2 Mapping Unit: 2a2

This unit refers to well-drained soils that occur on a very gently sloping land (1 to 2% slope). It covers 8.94 ha or 3.23% of the farm

Soils of the unit are very deep (>150 cm) and have a color of very dark gray (7.5YR3/1) to very dark brown (7.5YR2.5/2) when moist. The texture is clay moderate medium sub angular blocky structure. These soils have consistency that is friable when moist and sticky plastic when wet.

The pH of surface soil is 6.4 (slightly acid), increasing to 8.3 (moderately alkaline) in

subsurface horizons. The electrical conductivity is generally non-saline that ranges between 0.001 and 0.17 ds/m. The cation exchange capacity of the soils is very high (49.0 to 53.0 cmol (+)/kg soil and it is high to very highly base saturated (66 to 82%). The organic matter content is very low to medium (0.48 to 4.13%) and total nitrogen is low to medium (0.059 to 0.2%); while available phosphorous is low (0.44 to 3.54 ppm). Available micronutrients range between 5.72 to 20.34 ppm for Fe, 3.24 to 38.36 ppm for Mn, 0.14 to 0.44 ppm for Zn and 1.64 to 1.92 ppm for Cu.

4.1.3 Mapping Unit: 3a1

This unit refers to the well-drained soils that occur on gently sloping land (2 to 5% slope). It covers 4.37 ha or 1.58% of the farm.

Soils of the unit are very deep (> 150 cm) and have a color of dark brown (10YR5/3) when dry and dark brown (10YR3/3) when moist. The texture is loam with strong coarse sub-angular blocky structure. These soils have consistency that is slightly hard when dry, friable when moist and slightly sticky slightly plastic when wet.

The pH of surface soil is 7.3 (moderately alkaline), increasing to 9.1 (very alkaline) in subsurface horizons. The electrical conductivity is generally non-saline that ranges between 0.048 and 0.49 ds/m. The cation exchange capacity of the soils is medium to high (22.6 to 36.6 cmol (+)/kg soil and it is medium to very highly base saturated (60 to 95%). The organic matter content is very low to low (0.874 to 1.191%) and total nitrogen is very low to low (0.045 to 0.097%); while available phosphorous is low (0.6 to 3.6 ppm). Available micronutrients range between 3.24 to 7.08 ppm for Fe, 1.26 to 23.72 ppm for Mn, 0.54 to 1.4 ppm for Zn and 0.22 to 0.44 ppm for Cu.

4.1.4 Mapping Unit: 3a2

This unit refers to well-drained soils that occur on a very gently sloping land (2 to 5% slope). It covers 40.39 ha or 14.60% of the farm

Soils of the unit are very deep (>150 cm) and have a color of very dark gray (7.5YR3/1) to black (7.5YR2.5/1) when moist. The texture is clay with moderate medium sub-angular blocky structure. These soils have consistency that is friable when moist and sticky slightly plastic to plastic when wet.

The pH of surface soil is 6.5 (slightly acidic), increasing to 8.7(very alkaline) in subsurface horizons. The electrical conductivity is generally non-saline that ranges between 0.007 and 0.47 ds/m. The cation exchange capacity of the soils is very high (42.6 to 58.2 cmol (+)/kg soil and it is high to very highly base saturated (67 to 99%). The organic matter content is very low to high (0.34 to 4.51%) and total nitrogen is very low to low (0.024 to 0.19%); while available phosphorous is low to medium (0.42 to 8.84 ppm). Available micronutrients range between 3.98 to 16.86 ppm for Fe, 3.18 to 36.9 ppm for Mn, 0.16 to 0.68 ppm for Zn and 1.4 to 2.26 ppm for Cu.

4.1.5 Mapping Unit: 3a2*

This unit refers to well-drained soils that occur on a nearly level land (0 to 1% slope). It covers 14.68 ha or 5.31% of the farm

Soils of the unit are very deep (>150cm) and have a color of very dark brown (10YR2/2) when moist. The texture is clay with strong medium sub angular blocky structure. These soils have consistency that is friable when moist and sticky plastic when wet.

The pH of surface soil is 6.8(slightly acid), increasing to 8.1(moderately alkaline) in subsurface horizons. The electrical conductivity is generally non-saline that ranges between 0.005 and 0.009 ds/m. The cation exchange capacity of the soils is very high (44.2 to 50.6 cmol (+)/kg soil and it is highly base saturated (65 to 76%). The organic matter content is very low to high (0.898 to 4.469%) and total nitrogen is very low to medium (0.027 to 0.199%); while available phosphorous is low (0.22 to 1.88 ppm). Available micronutrients range between 8.02 to 19.4 ppm for Fe, 7.42 to 34.82 ppm for Mn, 0.26 to 0.48 ppm for Zn and 1.32 to 1.86 ppm for Cu.

4.1.6 Mapping unit: 3b2

This unit refers to well-drained soils that occur on a gently sloping land (2 to 5% slope). It covers 30.71 ha or 11.10% of the farm.

Soils of the unit are deep (100-150 cm) and have a color of Very dark brown (7.5YR2.5/2) when moist. The texture is clay with strong fine sub angular blocky structure. These soils have consistency that is friable when moist and sticky plastic when wet.

The pH of surface soil is 6.6 (slightly acid), increasing to 8.4 (moderately alkaline) in

subsurface horizons. The electrical conductivity is generally non-saline that ranges between 0.009 and 0.026 ds/m. The cation exchange capacity of the soils is high to very high (37 to 56.2 cmol (+)/kg soil and it is high to very highly base saturated (69 to 84%). The organic matter content is very low to medium (0.28to 3.58%) and total nitrogen is very low to low (0.02 to 0.15%); while available phosphorous is low (0.9 to 3.72 ppm). Available micronutrients range between 4.2 to 17.34 ppm for Fe and 2.56 to 35.1 ppm for Mn, 0.2 to 0.52 ppm for Zn and 0.88 to 2.24 ppm for Cu.

4.1.7 Mapping Unit: 3b2*

This unit refers to well-drained soils that occur on a gently sloping land (1 to 2% slope). It covers 38.30 ha or 13.85% of the farm.

Soils of the unit are moderately deep (50-100 cm) and have a color of very dark gray (7.5YR3/1) when moist. The texture is clay with strong medium sub angular blocky structure. These soils have consistency that is friable when moist and sticky plastic when wet.

The pH of surface soil is 8.3 (moderately alkaline), decreasing to 7.2 (moderately alkaline) in subsurface horizons. The electrical conductivity is generally non-saline that ranges between 0.013 and 0.023 ds/m. The cation exchange capacity of the soils is very high (45.2 to 55.8 cmol (+)/kg soil and it is high to very highly base saturated (71 to 88%). The organic matter content is very low to low (0.995 to 1.69%) and total nitrogen is very low to medium (0.034 to 0.2%); while available phosphorous is low to extremely high (0.78 to 21 ppm). Available micronutrients range between 4.48-to 9.0 ppm for Fe, 3.22 to 20.1 ppm for Mn, 0.12 to 0.48 ppm for Zn and 1.64 to 2.0 ppm for Cu.

4.1.8 Mapping Unit: 3b5

This unit refers to well-drained soils that occur on a gently sloping land (2 to 5% slope). It covers 5.50 ha or 1.99% of the farm

Soils of the unit are deep (100-150 cm) and have a color of Very dark gray (7.5YR3/1) when moist. The texture is clay loam with moderate medium sub-angular blocky structure. These soils have consistency that is friable when moist and sticky plastic when wet.

The pH of surface soil is 6.4 (slightly acid), increasing to 8.4 (moderately alkaline) in subsurface horizons. The electrical conductivity is generally non-saline that ranges between

0.017 and 0.026 ds/m. The cation exchange capacity of the soils is very high (41.6 to 53 cmol (+)/kg soil and it is high to very highly base saturated (73 to 95%). The organic matter content is very low to medium (0.28 to 3.44%) and total nitrogen is very low to low (0.041 to 0.16%); while available phosphorous is low to medium (0.76 to 9.36 ppm). Available micronutrients range between 4.54 to 17.9 ppm for Fe, 3.04 to 36.3 ppm for Mn, 0.12 to 0.42 ppm for Zn and 1.44 to 2.34 ppm for Cu.

4.1.9 Mapping Unit: 4a1

This unit refers to well-drained soils that occur on very gently sloping land (5 to 10 % slope). It covers 7.62 ha or 2.76% of the farm.

Soils of the unit are very deep (>150 cm) and have a color of very dark gray (7.5YR3/1) when moist. The texture is clay with moderate medium sub angular blocky structure. These soils have consistency that is friable when moist and sticky plastic when wet.

The pH of surface soil is 7.4(moderately alkaline), increasing to 8.7 (very alkaline) in subsurface horizons. The electrical conductivity is generally non-saline that ranges between 0.003 and 0.029 ds/m. The cation exchange capacity of the soils is high to very high (39.2 to 54.6 cmol (+)/kg soil and it is high to very highly base saturated (78 to 98%). The organic matter content is very low to medium (0.453 to 3.27) and total nitrogen ranges from very low to high (0.027 to 0.26%) while available phosphorous ranges from low to extremely high (0.24 to 23.16 ppm). Available micronutrients range between 5.24 to 13.16 ppm for Fe, 3.66 to 32.84 ppm for Mn, 0.2 to 1.58 ppm for Zn and 1.8 to 2.28 ppm for Cu.

4.1.10 Mapping Unit: 4c2

This unit refers to well-drained soils that occur on a gently sloping land (5 to 10% slope). It covers 12.09 ha or 4.37% of the farm

Soils of the unit are moderately deep (50-100 cm) and have a color of very dark gray (7.5YR3/1) when moist. The texture is clay with moderate to strong medium sub angular blocky structure. These soils have consistency that is friable when moist and sticky plastic when wet.

The pH of surface soil is 6.7 (slightly acidic), increasing to 8.6 (very alkaline) in subsurface horizons. The electrical conductivity is generally non-saline that ranges between 0.008 and

0.085 ds/m. The cation exchange capacity of the soils is very high (44.6 to 57.8 cmol (+)/kg soil and it is high to very highly base saturated (71 to 97%). The organic matter content is very low to medium (0.62 to 3.85%) and total nitrogen is very low to medium (0.022 to 0.23%); while available phosphorous is low (0.32 to 4.54 ppm). Available micronutrients range between 4.28 to 17.12 ppm for Fe, 3.32 to 38.28ppm for Mn, 0.08 to 0.68 ppm for Zn and 1.64to 2.44 ppm for Cu.

4.1.11 Mapping Unit: 4c1

This unit refers to moderately drained soils that occur on a sloping land (2 to 5% slope). It covers 7.96ha or 2.88% of the farm.

Soils of the unit are moderately deep (50-100cm) and have a color of black (7.5YR2.5/1) when moist. The texture is clay with strong medium sub- angular blocky structure. These soils have consistency that is friable when moist and very sticky plastic when wet.

The pH of surface soil is 6.4 (slightly acid), increasing to 7.0 (slightly acid) in subsurface horizons. The electrical conductivity is generally non-saline that ranges between 0.006 and 0.015 ds/m. The cation exchange capacity of the soils is very high (48.6 to 50.0 cmol (+)/kg soil and it is medium to highly base saturated (51 to 76%). The organic matter content is low to high (1.51 to 5.19%) and total nitrogen is low to medium (0.1 to 0.22%); while available phosphorous is low (0.42 to 3.32 ppm).Available micronutrients range between 10.08 to 15.86 ppm for Fe, 16.66 to 31.46 ppm for Mn, 0.32 to 0.54 ppm for Zn and 1.28-2.26 ppm for Cu.

Table 3 Summary characteristics of the mapping units of the SARC.

Mapping Unit	Slope %	Depth (Cm)	Texture (0-30 cm)	pH H ₂ O	EC dS/m	T.N %	OM %	Av. P ppm
1b2	0-1	100-150	Clay	6.5-7.3	0.005-0.011	0.031-0.22	1.04-2.68	1.6-9.96
2a2	1-2	>150	Clay	6.4-8.3	0.001-0.17	0.059-0.2	0.48-4.13	0.44-3.54
3a1	2-5	>150	Heavy Clay	7.3-9.1	0.48-0.49	0.045-0.097	0.42-3.66	0.6-3.6
3a2	2-5	>150	Clay	6.5-8.7	0.007-0.47	0.024-0.19	0.34-4.51	0.42-8.84
3a2*	0-1	>150	Clay	6.8-8.1	0.005-0.009	0.027-0.199	0.898-4.47	0.22-1.88
3b2	2-5	100-150	Clay	6.6-8.4	0.009-0.026	0.02-0.15	0.28-3.58	0.9-3.72
3b2*	2-5	50-100	Clay	7.2-8.3	0.013-0.023	0.034-0.2	0.99-1.69	0.78-21
3b5	2-5	100-150	Clay Loam	6.4-8.4	0.017-0.026	0.041-0.16	0.28-3.44	0.76-9.36
4a1	5-10	>150	Heavy Clay	7.4-8.7	0.003-0.029	0.027-0.26	0.453-3.27	0.24-23.16
4c1	5-10	50-100	Heavy Clay	6.4-7	0.006-0.015	0.1-0.22	1.51-5.19	0.42-3.32
4c2	5-10	50-100	Clay	6.7-8.6	0.008-0.085	0.022-0.23	0.48-3.85	0.32-4.54

Mapping Unit	Exchangeable bases (cmol (+) kg ⁻¹ soil)					BSP	Micronutrients (ppm)			
	Na	K	Ca	Mg	CEC		Fe	Mn	Zn	Cu
1b2	0.27-0.72	1.25-2.91	22.16-27.59	8.15-9.3	46.8-50.6	69-78	6.92-20.5	5.12-37.22	0.1-0.66	1.5-2.24
2a2	0.27-0.68	1.49-2.53	19.46-28.99	8.48-9.96	49.0-53.0	66-82	5.72-20.34	3.24-38.36	0.14-0.44	1.64-1.92
3a1	0.28-0.8	1.57-3.44	20.96-28.88	5.68-7.08	22.6-36.6	60-95	3.24-7.08	1.26-23.72	0.54-1.4	0.22-0.44
3a2	0.22-0.78	0.96-2.15	25.1-35.23	7.82-10.45	42.6-58.2	67-99	3.98-16.86	3.18-36.9	0.16-0.68	1.4-2.26
3a2*	0.34-0.56	1.7-2.17	17.47-25.05	9.05-11.6	44.2-50.6	65-76	8.02-19.4	7.42-34.82	0.26-0.48	1.32-1.86
3b2	0.2-0.37	1.12-2.4	24-29.24	5.76-10.04	37-56.2	69-84	4.2-17.34	2.56-35.1	0.2-0.52	0.88-2.24
3b2*	0.3-0.61	1.11-2.88	28.99-31.54	7.08-12.43	45.2-55.8	71-88	4.48-9.0	3.22-20.1	0.12-0.48	1.64-2.0
3b5	0.25-0.6	1-2.85	26.7-31.89	7.49-9.14	41.6-53.0	73-95	4.54-17.9	3.04—36.3	0.12-0.42	1.44-2.34
4a1	0.31-0.54	1.02-2.34	25.95-35.58	9.63-11.69	39.2-54.6	78-98	5.24-13.16	3.66-32.84	0.2-1.58	1.8-2.28
4c1	0.35-0.49	1.3-2.48	17.66-31.54	6.09-8.89	48.6-50	51-76	10.08-15.86	16.6-31.46	0.32-0.54	1.28-2.26
4c2	0.29-0.58	1.02-2.5	25.6-34.78	8.56-11.28	44.6-57.8	71-97	4.28-17.12	3.32-38.28	0.08-0.68	1.64-2.44

4.2 Overall Soil Physical and Chemical Characteristics

4.2.1 Physical Properties

Texture

The results of the particle size analysis indicate that the majority of the soils are fine textured containing higher proportions of clay (30 to 67%) throughout the horizons.

Soil structure

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

Soil depth

The soil depth of the soils varies from moderately deep (50–100cm) to very deep (> 150 cm). This indicates that soil depth is not limiting to most field crops.

Bulk Density

The bulk density (BD) of surface soils ranges from 0.85 to 0.96 g/cm³ while it is medium and ranges from 0.91 to 1.23 g/cm³ for the subsurface horizons. The low BD of the surface soils could be due to the relatively higher organic matter content. The overall BD values indicate that the soils are not compact to inhibit root development.

4.2.2 Chemical Properties

Soil reaction

The surface soils have slightly acidic to slightly alkaline reactions (pH 6.4 to 7.8) while subsurface soils have moderately to strongly alkaline reactions (pH 6.5 to 8.7). The pH values in KCl solution are consistently less than pH in H₂O indicating that the soils have net negative charge.

Electrical Conductivity

Electrical conductivity (EC) measurements are used as indications of total quantities of soluble salts in the soil. Electrical conductivity of the soils generally increases with soil depth. The EC values range from 0.001 to 0.49 dS m⁻¹ indicating that the soils are non-saline.

Organic carbon

The organic carbon (OC) content of the soils ranges from 0.16 to 4.19% and its content decreases regularly with soil depth. In almost all the soils the OC content of the upper 50 cm soil layer is > 1%. Such a high OC content of the soils could be due to the association of humic substances with Ca forming Ca-humate.

Total Nitrogen

The total nitrogen (TN) content of the soils is generally low (0.02 to 0.23%). Surface soils have higher values than subsurface soils.

Available Phosphorous

The available phosphorous content of the soils is low (< 15 ppm). Surface soils have higher P content than subsurface soils. Exceptionally high values (21 to 23 ppm) in the surface soils were obtained. The overall higher P content of the surface soils could be attributed to the regular application of P-fertilizer for experimental purposes.

Exchangeable Sodium Percentage (ESP)

The exchangeable sodium percentage generally increases with depth. Its values are < 2% and it indicates that the soils are not natric.

Cation exchange capacity and Base Saturation Percentage

The cation exchange capacity (CEC) of the soils ranges between 22.6 and 58.2 cmol_c kg⁻¹ soil and surface soils have higher CEC values than subsurface soils. The wider CEC range of the soils could be related to a difference in texture and clay mineralogy of the soils. The base saturation percentage generally increases with soil depth and the values range between 51 and 99%.

Cationic balance

The studied soils are moderately to highly base saturated. However, this does not prove a balanced proportion of the exchangeable bases. Thus, the basic cation saturation ratio and the relative proportions of the cations in the surface horizons were examined to evaluate the nutrient availability status of the soils (Table 4). According to Tisdale et al. (1993) the basic cation saturation ratios in the surface horizons indicate that the absolute amount of the exchangeable cations is adequate. The ratio of Ca to Mg indicates the presence of proportionate amounts of the two cations and implies absence of disruption in the nutrition of both cations. However, the ratio of (Ca+Mg) to K indicates that the relative proportion of K to (Ca + Mg) is high and this could likely inhibit Ca and Mg availability.

Table 4 The basic cation saturation ratio and their relative proportions in the surface horizons of the mapping units.

Mapping Unit	Ca/CEC		Mg/CEC		K/CEC		Ca/Mg		(Ca+Mg)/K	
		Status		Status		Status		Status		Status
1b2 (S5)	0.46	Adequate	0.17	Adequate	0.06	Adequate	2.72	proportional	10.4	High K
2a2 (S6)	0.44	Adequate	0.17	Adequate	0.05	Adequate	2.61	proportional	12.8	High K
2a2 (S10)	0.46	Adequate	0.20	Adequate	0.04	Adequate	2.29	proportional	15.2	High K
3a1 (S14)	0.53	Adequate	0.13	Adequate	0.03	Adequate	3.95	proportional	22.3	High K
3a2 (S7)	0.48	Adequate	0.16	Adequate	0.04	Adequate	2.95	proportional	18.3	High K
3a2 (S8)	0.54	Adequate	0.15	Adequate	0.04	Adequate	3.62	proportional	18.0	High K
3a2 (S11)	0.51	Adequate	0.12	Adequate	0.03	Adequate	4.28	proportional	18.7	High K
3a2*(S9)	0.40	Adequate	0.20	Adequate	0.05	Adequate	1.93	proportional	12.7	High K
3b2 (S1)	0.47	Adequate	0.17	Adequate	0.04	Adequate	2.69	proportional	14.8	High K
3b2*(S3)	0.53	Adequate	0.13	Adequate	0.05	Adequate	4.09	proportional	12.5	High K
3b5(S2)	0.50	Adequate	0.16	Adequate	0.05	Adequate	3.06	proportional	12.4	High K
4a1 (S12)	0.63	Adequate	0.19	Adequate	0.02	Adequate	3.35	proportional	41.0	High K
4c1 (S15)	0.53	Adequate	0.17	Adequate	0.05	Adequate	5.8	proportional	13.7	High K
4c2 (S4)	0.52	Adequate	0.17	Adequate	0.05	Adequate	2.95	proportional	15.0	High K
4c2 (S13)	0.44	Adequate	0.15	Adequate	0.03	Adequate	2.88	proportional	19.7	High K

(S5): Pedon Number

Micronutrients

Generally, the content of available micronutrients (Fe, Mn, Zn and Cu) tends to decrease with depth. The studied soils contain Fe and Mn in relatively high amounts; the levels in the surface layers are in the range of 6.88 to 20.50 and 7.02 to 39.2 ppm, respectively. On the other hand, the amount of Zn and Cu is low; the levels in the surface layers normally falling in the range of 0.42 to 1.58 and 1.28 to 2.34 ppm, respectively.

5. CONCLUSIONS

The predominant soil types at SARC are Phaeozems and Cambisols with minor occurrence of Vertisols. The soils are deep, fine textured and have aggregated soil structure with good porosity. All the soils are not saline and sodic. However, all the soils have low total nitrogen, available P, Zn and Cu. The absolute amounts of Ca, Mg and K are adequate in all the soils. The relative proportion among the three cations indicates K to be high and this may affect Ca and Mg availability. Thus future soil fertility improvement works should focus on the amelioration of chemical fertility problems of these soils.

Figure 1 Mapping Units of Sinana Agricultural Research Center

Figure 2 Soil Units of Sinana Agricultural Research Center.

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Annex 1. Soil profile descriptions

Date: 14/6/03

FIELD NO: S1
PROJECT: Sinana Agricultural Research Center
LOCATION: Sinana A.R.C
ALTITUDE: 2430m(altimeter)/2446m(GPS)
COORDINATES: N 7°06'59.7"E 40° 13' 16.7"
AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.
SOIL CLASSIFICATION: Luvic Phaezomes
SURROUNDING LANDFORM: Undulating Plain
PHYSIOGRAPHIC POSITION: Middle slope
LAND USE/COVER: Harvested field of Wheat.
SLOPE GRADIENT: 5%
MOISTURE CONDITION: Moist throughout.
DRAINAGE CLASS: well
GROUNDWATER DEPTH: Not observed
PARENT MATERIAL: Limestone
EROSION STATUS: Slight sheet at sight and surrounding
CLIMATE:
ROCK OUTCROPS: None
SURFACE STONES: None

Profile Description

- Ap 0 – 30/40cm Very dark brown (7.5YR2.5/2) moist; clay; strong fine sub angular blocky; sticky plastic wet, friable moist; many fine pores; many fine roots; clear and wavy boundary
- Bt1 30/40–72/84cm Black (10YR2/1) moist, clay; moderate medium prismatic; very sticky very plastic wet, friable moist; many distinct cutans; comon fine interstitial pores; many fine roots; clear and wavy boundary
- Bt 2 72/84 –112/117cm. Dark brown (10YR3/3) moist, clay loam; moderate medium angular blocky; slightly sticky slightly plastic wet, friable moist; few distinct cutans; few fine interstitial pores; few fine roots; gradual and smooth boundary.
- BC 112/117 –150cm. Dark yellowish brown (10YR3/6) moist, clay, moderate coarse angular blocky; slightly sticky slightly plastic, friable moist, many fine interstitial pores; few CaCO₃ concretions ; moderately calcareous, gradual smooth boundary.
- C150–200cm. Weathered gravel, highly cal carious.

FIELD NO: S2
 PROJECT: Sinana Agricultural Research Center
 LOCATION: Sinana A.R.C
 ALTITUDE: 2465m(GPS)/2460m(Altimeter)
 COORDINATES: N 7° 06' 51.1" E 40°13' 32.1"
 AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebe Ch.
 SOIL CLASSIFICATION: Luvic phaeozems
 SURROUNDING LANDFORM: Gently undulating Plain
 PHYSIOGRAPHIC POSITION: Lower slope
 LAND USE/COVER: Harvested field of Wheat
 SLOPE GRADIENT: 4%
 MOISTURE CONDITION: Moist throughout
 DRAINAGE CLASS: Well
 GROUNDWATER DEPTH: Not observed
 PARENT MATERIAL: limestone
 EROSION STATUS: Slight sheet at site and surrounding
 CLIMATE:
 ROCK OUTCROPS: None
 SURFACE STONES: None

Profile Description

AP 0 – 30 cm	Very dark gray (7.5YR3/1) moist; clay loam; moderate medium sub angular blocky; sticky plastic wet, friable moist; many fine interstitial pores; many fine roots; clear and smooth boundary.
Bt 30-100/105 cm	Black (7.5YR2.5/1) moist; clay; strong medium prismatic; slightly sticky plastic wet, friable moist; few fine cutans; many fine interstitial pores; many fine roots; clear and wavy boundary.
B 100/105 – 120/123 cm	Dark brown (7.5YR3/2) moist, clay; moderate medium prismatic; sticky plastic wet, friable moist; common fine roots, clear and wavy boundary
BC 120/123-147 cm	Dark brown (7.5YR3/2) moist, clay; medium prismatic; slightly sticky slightly plastic wet, friable moist; few fine roots; weakly calcareous; gradual and smooth boundary
C 1 147-175 cm.	Brown (7.5YR4/3) moist, clay, weathered, highly calcareous; clear and wavy boundary
C 2 175 –200+ cm	Very dark brown (7.5YR4/4) moist, clay, weathered, mediumCaCO ₃ rock fragments, highly calcareous; clear and wavy boundary

FIELD NO: S3

PROJECT: Sinana Agricultural Research Center

LOCATION: Sinana A.R.C

ALTITUDE: 2453m(GPS)

COORDINATES: N 7°06' 43.2" E 40°13' 26.0"

AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.

SOIL CLASSIFICATION: Haplic Phaeozems

SURROUNDING LANDFORM: Gently undulating plain

PHYSIOGRAPHIC POSITION: Middle slope

LAND USE/COVER: Harvested field of Wheat

SLOPE GRADIENT: 3%

MOISTURE CONDITION: Slightly moist throughout

DRAINAGE CLASS: Well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Limestone

EROSION STATUS: None at sight and slight sheet at surrounding

CLIMATE:

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap0 - 30 cm	Very dark gray (7.5YR3/1) moist; clay; strong medium sub angular blocky; sticky plastic wet, friable moist; many fine roots; clear smooth boundary.
B 30-76 cm	Black (10YR2/1) moist, clay loam; slightly sticky slightly plastic wet, friable moist, few fine roots; clear smooth boundary.
BC 76 –110cm	Dark brown (7.5YR 3/3) moist, clay; slightly sticky plastic wet, friable moist; gradual smooth boundary.
C1 110–168 cm	Brown (7.5YR 4/3) moist, clay; slightly sticky none plastic wet, friable moist; common weathered CaCO ₃ fragments; gradual smooth boundary
C2 168–210+ cm	Brown (7.5YR 4/3) moist, clay; slightly sticky none plastic wet, friable moist; common CaCO ₃ weathered fragments; gradual smooth boundary

Date: 14/6/03

FIELD NO: S4

PROJECT: Sinana Agricultural Research Center

LOCATION: Sinana A.R.C

ALTITUDE: 2451m(Gps)/2450m(altimeter)

COORDINATES: N 7°06' 33.9" E 40°13' 28.6"

AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.

SOIL CLASSIFICATION: Luvic Phaeozems

SURROUNDING LANDFORM: Undulating Plain

PHYSIOGRAPHIC POSITION: Upper slope

LAND USE/COVER: Cultivated field

SLOPE GRADIENT: 6%

MOISTURE CONDITION: Slightly moist

DRAINAGE CLASS: Well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Limestone

EROSION STATUS: Slightly sheet at sight and surrounding

CLIMATE:

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0-25 cm. Very dark gray (7.5YR3/1) moist; clay; strong medium sub angular blocky; sticky plastic wet, friable moist; many fine interstitial pores; many fine roots; clear smooth boundary.

B1 25-63cm. Black (10YR 2/1) moist; clay; strong medium sub angular blocky; slightly sticky slightly plastic wet, friable moist, common fine interstitial pores; common fine roots; clear smooth boundary.

B2 63-82/86cm. Black (7.5YR2.5/1) moist, clay; strong medium angular blocky; friable moist; common fine pores; few fine roots; moderately calcareous; gradual wavy boundary.

BC 82/86-110/125cm. Black (7.5YR2.5/1) moist; clay; moderate medium angular blocky; friable moist;
common fine pores; no roots observed; fine CaCO₃ rock fragments; highly calcareous; clear wavy boundary.

C 110/125-200+ cm. Brown (7.5YR4/4) moist; clay; weathered, fineCaCO₃ rock fragments; highly calcareous; no roots observed.

FIELD NO: S5

PROJECT: Sinana Agricultural Research Center

LOCATION: Sinana A.R.C

ALTITUDE: 2416m(Gps)/2450m(Altimeter)

COORDINATES: N 7°06' 21.8" E 40° 13' 19.0"

AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.

SOIL CLASSIFICATION: Haplic phaeozems

SURROUNDING LANDFORM: Alluvial Plain

PHYSIOGRAPHIC POSITION: Middle slope

LAND USE/COVER: Fallow

SLOPE GRADIENT: 0-1%

MOISTURE CONDITION: Slightly moist throughout

DRAINAGE CLASS: Well

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Aluvium-Colluvium

EROSION STATUS: None

CLIMATE:

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

- AP 0-23cm. Very dark gray (7.5YR3/1) moist; clay; strong medium sub angular blocky; friable moist, many fine pores many fine roots; clear smooth boundary.
- AB 23-70cm. Black 7.5YR 2.5/1) moist; clay; moderate medium sub angular blocky; friable moist, many fine interstitial pores; many fine roots; clear smooth boundary.
- B70-110cm. Very dark gray (10YR3/1) moist, clay; strong medium angular blocky; slightly sticky none plastic wet, friable moist; common fine interstitial pores; common fine roots; clear smooth boundary.
- BC110-155cm. Brown (7.5YR4/4) moist; silty clay; strong medium prismatic; slightly sticky none plastic wet, friable moist; few fine interstitial pores; no roots observed; clear smooth boundary.
- C 155-200+cm. Brown (7.5YR4/4) moist; clay; strong medium prismatic; friable moist; few fine interstitial pores.

FIELD NO: S6

PROJECT: Sinana Agricultural Research Center

LOCATION: Sinana Agricultural Research Center

ALTITUDE: 2412(GPS)/2420m

COORDINATES: N7°06' 31.3" E 40° 13' 04"

AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.

SOIL CLASSIFICATION: Haplic Phaeozems

SURROUNDING LANDFORM: Undulating Plain

PHYSIOGRAPHIC POSITION: Middle slope

LAND USE/COVER: Fallow

SLOPE GRADIENT: 1.5%

MOISTURE CONDITION: Moist throughout

DRAINAGE CLASS: well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Alluvial/Colluvial

EROSION STATUS: None at site and slight sheet at surrounding

CLIMATE:

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

- AP0-30 cm. Very dark gray (7.5 YR3/1) moist; clay; moderate medium sub angular blocky; slightly sticky slightly plastic wet, friable moist, many fine interstitial pores; many fine roots; clear smooth boundary.
- B 30-90cm. Very dark gray (10YR3/1) moist; clay; moderate medium prismatic; sticky slightly plastic wet, friable moist, common fine interstitial pores; common fine roots; gradual smooth boundary.
- AB 90-128 cm. Very dark grayish brown (10YR3/2) moist; clay loam; moderate medium angular blocky; sticky none plastic wet; friable moist; common fine interstitial pores; few fine roots; weakly calcareous; clear smooth boundary.
- Bk 128 - 200cm. Brown (7.5YR4/4) moist, clay loam; moderate medium sub angular blocky; sticky plastic wet, friable moist; common fine interstitial pores; moderately calcareous.

FIELD NO: S7
PROJECT: Sinana Agricultural Research Center
LOCATION: Sinana Agricultural Research Center
ALTITUDE: 2439(GPS) m
COORDINATES: N 7⁰ 06'47. 1 " E 40⁰ 13' 11.6"
AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.
SOIL CLASSIFICATION: Haplic Cambisols
SURROUNDING LANDFORM: Undulating plain
PHYSIOGRAPHIC POSITION: middle slope
LAND USE/COVER: Harvested filed of Teff
SLOPE GRADIENT: 3%
MOISTURE CONDITION: moist throughout
DRAINAGE CLASS: well drained
GROUNDWATER DEPTH: Not observed
PARENT MATERIAL: Basalt
EROSION STATUS: None at sight and slight sheet at surrounding
CLIMATE:
ROCK OUTCROPS: None
SURFACE STONES: None

Profile Description

- | | |
|------------------------|---|
| Ap 0-30 cm. | Very dark gray (7.5YR3/1) moist; clay; sticky slightly plastic wet, friable moist; many fine interstitial pores; common fine roots; clear smooth boundary. |
| A 30-63/70 cm. | Very dark brown (10YR2/2) moist, clay; moderate medium sub angular; sticky plastic wet, friable moist, common fine interstitial pores; many fine roots; gradual irregular boundary. |
| AB 63/70-114/127cm. | Dark brown (10YR3/3) moist, clay; moderate medium angular blocky; slightly sticky slightly plastic wet, friable moist; many fine interstitial pores; few fine roots; weakly calcareous; gradual and irregular boundary. |
| B1 114/127- 200/207cm. | Dark brown (7.5YR3/4) moist, clay; moderate medium angular blocky; slightly sticky slightly plastic wet, friable moist; many fine interstitial pores; common CaCO ₃ fragments; weakly calcareous; clear wavy boundary. |
| B2 200/207-230 cm. | Brown (7.5YR4/4) moist, clay loam; moderate medium sub angular blocky; slightly sticky none plastic wet, friable moist; many fine interstitial pores; no roots; moderately calcareous. |

FIELD NO: S8
PROJECT: Sinana Agricultural Research Center
LOCATION: Sinana Agricultural Research Center
ALTITUDE: 2468(GPS) m/2480
COORDINATES: N 7⁰ 06'59. 7 " E 40⁰ 13' 21.5"
AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.
SOIL CLASSIFICATION: Haplic Cambisols
SURROUNDING LANDFORM: Undulating plain
PHYSIOGRAPHIC POSITION: upper slope
LAND USE/COVER: Harvested field of Wheat
SLOPE GRADIENT: 4%
MOISTURE CONDITION: moist throughout
DRAINAGE CLASS: well
GROUNDWATER DEPTH: Not observed
PARENT MATERIAL: Basalt
EROSION STATUS: Slight sheet both at site and at surrounding
CLIMATE:
ROCK OUTCROPS: None
SURFACE STONES: None

Profile Description

- Ap 0-30 cm. Black (7.5YR2.5/1) moist; Clay; sticky plastic wet, friable moist; many fine interstitial pores; many few roots; clear smooth boundary.
- AB k1 30-55 cm. Black (7.5YR2.5/1) moist, Clay loam; sticky plastic wet, friable moist, common fine interstitial pores; common fine roots; highly calcareous; gradual smooth boundary.
- AB k2 55-105 cm. Very dark brown (7.5YR2.5/2) moist, Clay loam; moderate medium sub angular blocky; sticky slightly plastic wet, friable moist; common fine interstitial pores; highly calcareous; gradual smooth boundary.
- B k1 105-164cm. Brown (7.5YR4/3) moist, Clay; moderate medium sub angular blocky; slightly sticky none plastic wet, friable moist; many fine interstitial pores; common CaCO₃ fragments; highly calcareous; clear smooth boundary.
- B k2 164-200 +cm. Brown (7.5YR4/4) moist, Clay; moderate medium sub angular blocky; slightly sticky none plastic wet, friable moist; many fine interstitial pores; weakly calcareous.

FIELD NO: S9

PROJECT: Sinana Agricultural Research Center

LOCATION: Sinana Agricultural Research Center

ALTITUDE: 2412m(GPS)/2440

COORDINATES: N 7⁰ 06'49. 9 " E 40⁰ 12' 53.6"

AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.

SOIL CLASSIFICATION: Haplic Phaeozems

SURROUNDING LANDFORM: Flat plain

PHYSIOGRAPHIC POSITION: middle slope

LAND USE/COVER: Fallow

SLOPE GRADIENT: 4%

MOISTURE CONDITION: moist throughout

DRAINAGE CLASS: well

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Alluvial/Colluvial

EROSION STATUS: Slight sheet at surrounding and none at site

CLIMATE:

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0-30 cm	Very dark brown (10YR2/2) moist; clay; strong medium sub angular blocky; friable moist; many fine interstitial pores; many fine roots; clear smooth boundary.
A 30-84 cm	Very dark gray (7.5YR3/1) moist, clay; moderate medium prismatic; sticky plastic wet, friable moist, common fine interstitial pores; common fine roots; clear and smooth boundary
B1 84-120cm	Dark brown (7.5YR3/3) moist, clay; moderate medium prismatic; slightly sticky none plastic wet, friable moist; many fine interstitial pores; few fine roots; gradual smooth boundary.
B2 120-200+cm	Dark brown (7.5YR3/4) moist, clay; moderate medium sub angular blocky; slightly sticky none plastic wet, friable moist; common fine interstitial pores

FIELD NO: S10

PROJECT: Sinana Agricultural Research Center

LOCATION: Sinana Agricultural Research Center

ALTITUDE: 2416Gps/2461Alt

COORDINATES: N 07° 06'38.4" E 40° 12'45.2"

AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.

SOIL CLASSIFICATION: Haplic Phaozems

SURROUNDING LANDFORM: Undulating plain.

PHYSIOGRAPHIC POSITION: middle slope

LAND USE/COVER: Fallow

SLOPE GRADIENT: 1-2%

MOISTURE CONDITION: Moist throughout

DRAINAGE CLASS: well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL:

EROSION STATUS: None

CLIMATE:

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0 - 32 cm	Very dark brown (7.5YR2.5/2) moist; clay; moderate medium sub angular blocky; sticky plastic wet, friable moist, many fine interstitial pores; many fine roots; clear smooth boundary.
A 32-79cm	Very dark brown (10YR2/2) moist, clay; moderate medium sub angular blocky; sticky slightly plastic wet, friable moist, many fine roots; Gradual smooth boundary.
AB 79-108cm	Dark brown (7.5YR3/2) moist, clay; strong medium prismatic; sticky slightly plastic wet, friable moist; many fine interstitial pores; few fine roots; clear smooth boundary.
B 108-193 cm	Dark brown (7.5YR3/4) moist; clay; strong fine prismatic; slightly sticky none plastic wet, friable moist; many fine interstitial pores;

FIELD NO: S11

PROJECT: Sinana Agricultural Research Center

LOCATION: Sinana Agricultural Research Center

ALTITUDE: 2416GPS

COORDINATES: N 07° 06'54.1" E 40° 13'03.1"

AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.

SOIL CLASSIFICATION: Haplic Cambisols

SURROUNDING LANDFORM: Gently undulating

PHYSIOGRAPHIC POSITION: Upper slope

LAND USE/COVER: Harvested field of wheat

SLOPE GRADIENT: 4.5%

MOISTURE CONDITION: Moist through out

DRAINAGE CLASS: Well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL:

EROSION STATUS: Slight sheet both at sight and surrounding

CLIMATE:

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

- Ap 0 - 25 cm Very dark gray (7.5YR3/1) moist; clay; moderate medium sub angular blocky; sticky slightly plastic wet, friable moist; many fine interstitial pores; many fine roots; clear smooth boundary.
- A 25-55/64cm Very dark brown (10YR2/2) moist, clay; moderate medium angular blocky; sticky plastic wet, friable moist, many fine interstitial pores; common fine roots; abrupt and wavy boundary.
- Bk1 55/64-120 cm Dark brown (7.5YR3/3) moist; clay; moderate medium angular blocky; sticky slightly plastic wet, friable moist; many fine interstitial pores; highly calcareous; few fine roots; gradual smooth boundary.
- Bk2 120-200+cm Dark brown (7.5YR3/3) moist; clay; moderate fine angular blocky; friable moist, common fine interstitial pores; common calcium carbonate rock fragment; highly calcareous;

FIELD NO: S12

PROJECT: Sinana Agricultural Research Center

LOCATION: Sinana Agricultural Research Center

ALTITUDE: 2434GPS/2500Alt

COORDINATES: N 7⁰ 07'19.6" E 40° 13' 17.8"

AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.

SOIL CLASSIFICATION: Vertic Cambisols

SURROUNDING LANDFORM: Hilly

PHYSIOGRAPHIC POSITION: Upper slope

LAND USE/COVER:

SLOPE GRADIENT: 7%

MOISTURE CONDITION: Moist throughout

DRAINAGE CLASS: Well drained

GROUNDWATER DEPTH:

PARENT MATERIAL:

EROSION STATUS: Slight sheet both at sight and surrounding

CLIMATE:

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

- | | |
|----------------|---|
| Ap 0-24 cm | Very dark gray (7.5YR3/1) moist; clay; moderate medium sub angular blocky; sticky slightly plastic wet, friable moist; many fine interstitial pores; many fine roots; clear smooth boundary. |
| A 24-50cm | Very dark grayish brown (10YR3/2) moist, clay; strong medium angular blocky; sticky slightly plastic wet, friable moist, common fine interstitial pores; many fine roots; clear and smooth boundary. |
| AB 50-76/86cm | Very dark gray (7.5YR3/1) moist, clay; strong medium angular blocky; sticky plastic wet, friable moist; many fine interstitial pores; common fine roots; few faint slickensides; clear and wavy boundary. |
| B 76/86-120 cm | Dark brown (7.5YR3/2) moist; clay; strong medium sub angular blocky; slightly sticky slightly plastic wet; many fine interstitial pores; few fine roots; gradual smooth boundary. |
| BC 120-180+cm | Dark yellowish brown (10YR3/6) moist, clay; strong medium prismatic; slightly sticky none plastic wet, many fine interstitial pores; common calcium carbonate rock fragments. |

Date: 24/6/2003

FIELD NO: S13

PROJECT: Sinana Agricultural Research Center

LOCATION: Sinana Agricultural Research Center

ALTITUDE: 2448GPS/2490Alt

COORDINATES: N 07° 06'07.2" E 40° 13'17.4"

AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.

SOIL CLASSIFICATION: Luvic Phaeozems

SURROUNDING LANDFORM: Undulating to rolling plain

PHYSIOGRAPHIC POSITION: middle slope

LAND USE/COVER: Harvested field of wheat

SLOPE GRADIENT: 6%

MOISTURE CONDITION: Moist throughout

DRAINAGE CLASS: well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL:

EROSION STATUS: Slightly sheet both at sight and surrounding

CLIMATE:

ROCK OUTCROPS: None

SURFACE STONES: None

Profile Description

Ap 0-20 cm	Very dark gray (7.5YR3/1) moist; clay; moderate medium sub angular blocky; sticky plastic wet, friable moist, many fine interstitial pores; many fine roots; clear smooth boundary.
Bt 20-75cm	Black (7.5YR2.5/1) moist, clay; moderate medium angular blocky; sticky slightly plastic wet, friable moist, few distinct cutans; many fine interstitial pores; common fine roots; clear smooth boundary.
BC75-105cm	Dark brown (7.5YR3/2) moist, clay; moderate medium sub angular blocky; sticky plastic wet, friable moist; many fine interstitial pores; gradual and smooth boundary.
C 105-200cm	Strong brown (7.5YR4/6) moist; clay; moderate medium angular blocky; slightly sticky slightly plastic wet, friable moist; many fine interstitial pores; common calcium carbonate rock fragments; highly calcareous.

FIELD NO: S14
PROJECT: Sinana Agricultural Research Center
LOCATION: Sinana Agricultural Research Center
ALTITUDE: 2464Gps/2470Alt
COORDINATES: N 07° 06'45.5" E 40° 13'37.3"
AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.
SOIL CLASSIFICATION: Vertic Cambisols
SURROUNDING LANDFORM: Gently undulating
PHYSIOGRAPHIC POSITION: Upper slope
LAND USE/COVER: Harvested field of wheat
SLOPE GRADIENT: 4%
MOISTURE CONDITION: Moist through out
DRAINAGE CLASS: Well drained
GROUNDWATER DEPTH: Not observed
PARENT MATERIAL:
EROSION STATUS: Slightly sheet both at sight and surrounding
CLIMATE:
ROCK OUTCROPS: None
SURFACE STONES: None

Profile Description

- Ap 0 - 25 cm Very dark gray (7.5YR3/1) moist; clay; moderate medium sub angular blocky; sticky slightly plastic wet, friable moist; many fine interstitial pores; many fine roots; clear smooth boundary.
- A 25-50cm Very dark gray (7.5YR3/1) moist, clay; moderate medium angular blocky; sticky slightly plastic wet, friable moist, many fine interstitial pores; many fine roots; clear smooth boundary.
- B 50-90 cm Black (7.5YR2.5/1) moist; silty clay loam; moderate medium prismatic; sticky plastic wet, friable moist; few faint cutans; many fine interstitial pores; few manganese concretion; few fine roots; clear smooth boundary.
- Bk 90-160 cm Dark brown (7.5YR3/4) moist; clay; moderate medium angular blocky; slightly sticky none plastic, friable moist, common CaCO₃ rock fragments; many fine interstitial pores; few manganese concretions; clear smooth boundary.
- BCk 160-200+cm Dark brown (7.5YR3/4) moist; clay; moderate medium sub angular blocky; slightly sticky none plastic, friable moist, many fine interstitial pores; common calcium carbonate rock fragments.

FIELD NO: S15

PROJECT: Sinana Agricultural Research Center

LOCATION: Sinana Agricultural Research Center

ALTITUDE: 2455GPS/2470Alt

COORDINATES: N 7⁰ 06'53.8" E 40° 13' 39.1"

AUTHOR (S): Gebeyehu B., Ashenafi A., Tibebu Ch.

SOIL CLASSIFICATION: Eutric Vertisols

SURROUNDING LANDFORM: Gently undulating

PHYSIOGRAPHIC POSITION: Upper slope

LAND USE/COVER: Cultivated land

SLOPE GRADIENT: 5.5%

MOISTURE CONDITION: Moist throughout

DRAINAGE CLASS: Moderately well drained

GROUNDWATER DEPTH: Not observed

PARENT MATERIAL: Basalt

EROSION STATUS: Slight sheet both at sight and surrounding

CLIMATE:

ROCK OUTCROPS: None

SURFACE STONES: Few stones

Profile Description

Ap 0-20 cm	Black (7.5YR2.5/1) moist; clay; strong medium sub angular blocky; sticky plastic wet, friable moist; medium fine interstitial pores; many fine roots; clear and smooth boundary.
A 20-50cm	Black (10YR2/1) moist, clay; strong coarse prismatic; very sticky plastic wet, friable moist, common fine interstitial pores; many fine roots; common distinct slicken sides, clear smooth boundary.
AC 50-70cm	Very dark gray (10YR3/1) moist, strong medium angular blocky; sticky plastic wet, friable moist; many fine interstitial pores; common fine roots; common boulders and stones.

Annex 2. Climatic Data

A) Mean Monthly Rainfall

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1990	23.00	46.30	94.70	162.80	71.20	16.30	21.20	97.80	157.60	114.50	36.50	22.00	863.90
1991	22.40	27.10	108.20	95.40	125.80	31.40	90.70	124.30	93.20	25.70	10.10	16.40	770.70
1992	29.80	25.90	13.40	95.10	165.20	93.90	30.60	168.70	156.80	118.90	43.50	58.00	999.80
1993	47.40	85.50	0.00	117.80	94.50	18.00	25.20	73.50	148.30	98.10	17.00	8.90	734.20
1994	0.00	0.00	52.60	96.00	157.50	27.20	46.10	116.80	137.40	103.50	85.00	22.70	844.80
1995	0.00	16.80	80.60	133.10	102.40	90.60	53.10	108.50	116.10	73.20	9.20	9.30	792.90
1996	24.30	7.60	80.80	158.80	83.60	171.40	65.30	136.60	154.70	100.10	24.00	10.90	1018.10
1997	1.20	0.00	56.60	111.00	78.10	91.40	41.00	53.60	96.90	124.30	83.30	5.90	743.30
1998	75.00	5.30	38.30	48.00	115.90	35.20	73.80	67.10	94.40	138.80	23.50	0.50	715.80
1999	0.00	0.00	83.70	75.50	89.00	38.40	71.20	144.40	101.90	97.60	27.80	0.00	729.50
2000	1.80	0.00	13.30	76.60	120.40	31.40	68.80	64.20	121.80	116.80	26.60	10.70	652.40
2001	0.00	12.10	86.60	103.60	126.20	110.90	81.00	74.90	162.00	76.80	28.30	12.30	874.70
Mean	18.74	18.88	59.07	106.14	110.82	63.01	55.67	102.53	128.43	99.03	34.57	14.80	811.68

b) Mean Monthly Maximum Temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1990	21.68	21.96	20.78	20.49	21.78	22.61	22.55	21.41	17.85	19.80	20.09	21.51	21.04
1991	22.85	23.22	22.58	20.83	20.93	21.54	20.41	20.54	20.57	21.03	20.54	20.59	21.30
1992	21.81	21.60	22.30	21.30	20.62	20.54	20.77	20.38	19.70	18.91	18.78	20.03	20.56
1993	19.96	20.39	22.10	19.40	20.24	21.27	20.76	20.70	20.17	18.45	19.26	21.34	20.34
1994	23.57	22.89	24.46	21.51	21.49	22.76	22.97	21.70	21.00	20.80	20.59	22.76	22.21
1995	23.23	23.52	20.91	20.90	21.37	22.26	21.43	21.20	19.82	18.77	19.71	21.07	21.18
1996	22.34	23.33	20.31	19.67	19.91	19.68	19.68	19.38	20.40	20.27	20.23	20.77	20.50
1997	23.27	24.66	21.09	19.10	19.82	19.98	22.29	21.06	19.40	18.22	19.37	19.95	20.68
1998	21.71	23.19	22.98	22.81	22.53	22.68	20.64	20.43	19.52	18.91	19.93	21.73	21.42
1999	22.47	23.19	21.29	21.10	21.05	21.59	20.85	20.25	19.76	19.05	19.80	21.38	20.98
2000	22.28	23.43	23.34	21.61	22.45	20.41	19.71	19.87	18.65	18.80	19.87	22.01	21.04
2001	22.96	23.91	22.16	22.51	22.47	20.25	19.83	21.58	19.85	19.65	19.86	22.55	21.47
Mean	22.34	22.94	22.03	20.94	21.22	21.30	20.99	20.71	19.72	19.39	19.84	21.31	21.06

c) Mean Monthly Minimum Temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1990	7.68	10.50	9.86	10.36	9.93	9.41	9.15	15.03	11.30	6.82	7.45	6.23	9.48
1991	9.11	6.75	10.39	10.55	10.55	9.80	9.38	9.36	6.03	8.77	8.10	6.85	8.80
1992	9.58	9.62	10.73	10.82	9.95	9.38	9.41	8.86	9.62	8.28	7.00	8.74	9.33
1993	9.23	8.39	9.27	10.33	10.09	9.39	9.47	9.55	9.86	10.11	7.73	7.40	9.23
1994	7.55	8.53	10.13	10.38	9.63	9.92	9.65	9.73	10.31	8.50	7.54	5.90	8.98
1995	6.65	8.73	9.82	10.85	9.36	9.52	10.04	9.77	9.80	8.91	7.50	7.68	9.05
1996	7.78	9.71	10.47	10.79	10.05	9.33	9.44	9.08	9.80	7.65	7.96	7.12	9.10
1997	9.36	7.46	11.15	11.15	9.64	9.15	10.32	9.26	10.28	10.94	9.87	8.83	9.78
1998	9.96	10.06	11.17	11.94	11.65	10.94	10.87	11.18	10.82	10.90	6.10	5.75	10.11
1999	7.41	9.28	10.07	11.21	9.75	10.03	9.95	9.62	10.15	9.55	6.43	7.29	9.23
2000	7.01	9.20	10.18	10.51	10.03	10.48	10.11	10.45	10.00	10.00	7.16	6.84	9.33
2001	8.05	8.58	10.56	10.87	10.62	9.51	8.88	9.82	10.93	9.69	7.95	6.77	9.35
Mean	8.28	8.90	10.32	10.81	10.10	9.74	9.72	10.14	9.91	9.18	7.57	7.12	9.32

Annex 3. Analytical data of the soils

Mapping Unit	Pedon No	Depth (cm)	PH (H ₂ O)	pH KCl	EC ds/m	Sand	Silt	Clay	Texture	Exchangeable Bases (cmol _c kg ⁻¹ soil)					Bas.Sa %	T.N %	O.C %	Av.P.OI. Ppm	Micro Nutrients (ppm)				F.C %	P.W.P %	B.D g/cm ³	
										Class	Na	K	Ca	Mg					CEC	Fe	Mn	Zn				Cu
3b2	S-1	0-30/40	6.6	5.3	0.018	29	26	45	C	0.20	2.40	25.95	9.63	55.20	69	0.147	2.075	3.72	17.34	35.10	0.52	2.14	-	-	-	
		30/40-72/84	7.2	5.8	0.009	17	22	61	C	0.23	1.46	28.04	9.88	56.20	70	0.085	1.277	0.90	5.36	5.12	0.26	2.00	-	-	-	
		72/84-112/117	8.0	6.7	0.026	35	26	39	CL	0.36	1.32	29.24	10.04	49.80	82	0.070	0.7581	3.40	10.44	14.62	0.20	2.24	-	-	-	
		150-200	8.4	7.3	0.017	31	20	49	C	0.37	1.12	24.00	5.76	37.00	84	0.020	0.1596	1.14	4.20	2.56	0.08	0.88	-	-	-	
3b5	S-2	0-30	6.4	5.6	0.017	33	32	35	CL	0.27	2.85	26.70	8.72	53.00	73	0.161	1.995	9.36	17.90	36.30	0.42	2.34	-	-	-	
		30-100/115	7.4	6.1	0.024	25	28	47	C	0.25	1.00	28.99	8.39	52.60	73	0.084	1.2768	0.82	7.36	11.16	0.14	2.24	-	-	-	
		100/105-120-123	8.0	6.9	0.026	19	32	49	C	0.39	1.23	31.89	9.14	52.60	81	0.062	0.8778	0.78	5.22	4.54	0.16	2.00	-	-	-	
		120/123-147	8.1	7.0	0.026	19	22	59	C	0.60	1.29	31.19	8.89	51.80	81	0.062	0.4389	0.74	4.96	3.28	0.06	1.80	-	-	-	
		147-175/180	8.3	7.2	0.023	19	32	49	C	0.43	1.16	28.34	7.49	41.60	90	0.041	0.2195	0.78	4.94	3.04	0.28	1.56	-	-	-	
		175-200+	8.4	7.2	0.019	19	24	57	C	0.55	1.04	30.94	8.72	43.20	95	0.041	0.160	0.76	4.54	3.14	0.12	1.44	-	-	-	
3b2*	S-3	0-30	8.3	6.4	0.015	27	26	47	C	0.30	2.88	28.99	7.08	55.20	71	0.209	2.374	21.00	6.98	20.10	0.48	1.66	-	-	-	
		30-76	7.2	6.0	0.013	29	42	29	CL	0.30	2.06	29.29	9.71	55.80	74	0.091	1.416	1.54	9.00	16.42	0.24	2.00	-	-	-	
		70-110	8.1	7.0	0.023	19	20	61	C	0.330	1.44	30.34	9.55	51.60	81	0.081	0.838	0.78	4.80	4.14	0.12	1.80	-	-	-	
		110-168	8.3	7.1	0.021	17	26	57	C	0.390	1.11	29.54	8.23	45.20	87	0.067	0.439	0.84	4.48	4.06	0.26	1.74	-	-	-	
		168-210+	8.3	7.1	0.022	23	20	57	C	0.610	1.34	31.54	12.43	52.00	88	0.034	0.439	1.26	4.96	3.22	0.12	1.64	-	-	-	
4c2	S-4	0-25	6.7	5.6	0.085	17	32	51	C	0.330	2.50	27.94	9.46	54.20	74	0.141	2.234	3.90	15.14	38.28	0.68	1.98	-	-	-	
		25-63	7.0	5.8	0.008	19	24	57	C	0.400	1.15	29.99	8.56	56.40	71	0.123	1.756	1.10	9.50	24.12	0.16	2.44	-	-	-	
		63-82/85	8.2	7.0	0.017	19	24	57	C	0.290	1.02	33.68	9.22	53.80	82	0.085	1.377	0.78	6.96	5.62	0.16	1.86	-	-	-	
		82/85-110/125	8.3	7.1	0.017	33	32	35	C	0.480	1.34	34.78	11.19	51.80	92	0.088	1.197	0.56	4.28	4.80	0.08	1.82	-	-	-	
		110/125-200	8.4	7.2	0.025	17	32	51	C	0.580	1.26	31.84	11.28	49.00	92	0.022	0.279	0.40	4.64	3.48	0.10	1.68	-	-	-	
1b2	S-5	0-23	6.5	5.6	0.011	19	30	51	C	0.270	2.91	22.16	8.15	48.60	69	0.217	3.272	9.96	20.50	37.22	0.66	1.96	-	-	-	
		23-70	6.5	5.2	0.006	15	30	55	C	0.33	2.52	23.80	9.14	49.20	73	0.099	1.676	7.14	18.02	34.36	0.42	2.24	-	-	-	
		70-110	7.3	5.9	0.005	21	36	43	C	0.54	2.75	23.35	7.82	46.80	74	0.066	1.057	1.60	10.00	16.66	0.26	2.12	-	-	-	
		110-155	8.0	6.5	0.008	29	30	41	C	0.72	1.46	27.59	9.30	50.20	78	0.053	0.618	2.94	7.08	6.58	0.10	2.08	-	-	-	
		155-200+	8.0	6.2	0.008	35	26	39	C	0.480	1.25	27.40	8.56	50.60	74	0.031	0.219	3.48	6.92	5.12	0.20	1.50	-	-	-	
2a2	S-6	0-30	6.4	5.3	0.001	25	32	43	C	0.270	2.53	23.45	8.97	53.00	66	0.172	2.354	3.34	20.34	38.36	0.42	1.82	50.0	39.0	0.90	
		30-90	7.3	5.8	0.005	27	32	41	C	0.440	1.84	26.15	9.22	51.80	73	0.076	1.097	0.82	9.24	14.60	0.16	1.70	43.6	42.4	1.18	
		90-128	8.3	5.4	0.008	35	32	33	CL	0.650	1.83	28.34	9.71	49.60	82	0.063	0.738	2.18	6.40	6.04	0.14	1.64	46.0	41.5	1.12	
		128-200+	8.3	7.0	0.017	35	28	37	CL	0.680	1.49	28.99	9.96	52.40	78	0.045	0.279	1.02	5.72	3.24	0.22	1.60	-	-	-	
3a2	S-7	0-30	6.5	5.4	0.017	21	28	51	C	0.410	1.94	26.45	8.97	55.00	69	0.188	2.175	8.84	16.86	36.90	0.44	1.72	53.0	38.0	0.98	
		30-63/70	7.1	5.7	0.007	27	26	47	C	0.300	1.29	29.84	9.88	49.94	83	0.080	1.337	0.68	11.32	22.96	0.24	1.66	41.6	34.8	0.91	
		63/70-114/127	8.5	6.2	0.007	27	26	47	C	0.330	1.11	30.94	10.04	55.60	76	0.077	0.998	0.64	7.30	9.64	0.20	1.56	44.3	45.3	1.04	
		114/127-200/207	8.7	7.1	0.024	25	32	43	C	0.440	1.20	30.69	9.88	42.60	99	0.041	0.299	0.60	4.72	3.64	0.16	1.40	-	-	-	
		200/207-230+	8.7	7.1	0.023	31	34	35	CL	0.57	1.21	27.05	10.45	47.80	82	0.028	0.200	0.58	4.84	3.18	0.24	2.12	-	-	-	

Mapping Unit	Pedon No	Depth(cm)	pH H ₂ O	pH KCl	EC ds/m	Sand	Silt	Clay	Texture	Exchangeable Bases (cmol _c kg ⁻¹ soil)					Bas.Sa %	T.N %	O.C %	Av.P ppm	Micro Nutrients (ppm)				F.C %	P.W.P %	B.D g/cm ³
						% Class			Na	K	Ca	Mg	CEC	Fe					Mn	Zn	Cu				
3a2	S-8	0-30	7.3	5.9	0.031	21	30	49	C	0.22	2.150	30.39	8.390	56.00	73	0.133	1.995	5.22	13.50	32.90	0.62	2.26	43.5	36.7	0.98
		30-55	8.6	7.1	0.026	27	36	35	CL	0.26	0.96	35.23	8.150	53.0	84	0.120	1.397	1.58	3.98	7.88	0.32	1.56	39.9	39.2	0.98
		55-105	8.5	7.0	0.033	29	38	33	CL	0.380	1.09	30.89	9.96	52.00	81	0.091	1.177	1.40	4.66	7.30	0.40	2.26	42.7	41.5	0.98
		105-164	8.5	7.1	0.037	27	38	43	C	0.780	1.11	29.99	9.71	45.80	91	0.052	0.399	1.20	4.88	4.00	0.26	1.56	-	-	-
		164-200+	8.5	7.1	0.047	23	32	45	C	0.710	1.20	25.10	8.39	44.40	80	0.059	0.379	4.08	4.72	5.18	0.66	1.76	-	-	-
3a2*	S-9	0-30	6.8	5.2	0.009	17	32	61	C	0.340	2.09	17.47	9.05	44.20	65	0.199	2.474	1.88	19.40	34.82	0.48	1.80	45.7	36.5	0.96
		30-84	7.4	5.5	0.006	19	26	55	C	0.340	2.17	22.80	11.19	49.40	74	0.066	1.057	0.36	14.24	27.70	0.30	1.86	49.7	40.4	1.21
		84-120	8.1	6.0	0.005	19	28	53	C	0.340	1.70	25.05	11.19	50.60	76	0.043	0.499	0.22	10.22	15.48	0.26	1.66	36.4	46.0	1.23
		120-200+	8.4	6.3	0.008	23	28	49	C	0.560	1.59	22.21	11.60	49.60	73	0.027	0.219	0.56	8.02	7.42	0.38	1.32	-	-	-
2a2	S-10	0-32	6.9	5.2	0.008	23	32	45	C	0.370	1.84	19.46	8.48	42.00	72	0.196	2.394	3.54	18.52	34.42	0.44	1.90	54.92	35.09	0.98
		32-79	7.6	5.6	0.005	15	34	51	C	0.460	1.86	21.36	9.46	49.00	68	0.073	1.057	0.60	10.54	26.12	0.40	1.92	33.51	44.69	1.00
		79-180	8.1	6.0	0.006	19	24	57	C	0.47	1.49	25.30	9.96	51.60	72	0.059	0.698	0.44	8.58	13.80	0.32	1.84	37.05	36.70	1.07
3a2	S-11	0-25	7.0	5.6	0.018	23	32	45	C	0.26	1.950	29.59	6.910	58.20	67	0.186	2.613	8.00	14.36	39.24	0.68	1.92	32.84	39.84	0.92
		25-55	7.1	5.6	0.014	19	24	57	C	0.35	1.57	30.34	6.580	56.0	69	0.136	1.855	2.08	13.02	31.34	0.44	1.94	47.02	41.58	1.09
		55/64-120	8.5	7.0	0.022	23	34	43	C	0.420	1.27	34.98	7.82	53.60	83	0.084	1.137	0.60	4.04	4.14	0.26	1.88	47.00	44.71	1.03
		120-200	8.7	7.1	0.023	15	28	57	C	0.460	1.23	32.09	8.48	43.60	97	0.024	0.219	0.42	5.08	3.5	0.28	1.40	-	-	-
4a1	S-12	0-24	7.4	6.2	0.048	19	26	55	C	0.310	1.02	32.24	9.63	50.94	85	0.262	4.190	23.16	13.16	32.84	1.58	1.92	38.26	47.48	0.86
		24-50	7.9	6.2	0.012	19	26	55	C	0.370	1.25	30.49	10.21	52.26	81	0.106	1.776	1.02	10.2	19.72	0.34	1.88	36.15	50.81	1.06
		50-76/86	8.2	6.6	0.023	21	28	51	C	0.480	1.27	35.58	11.69	49.94	98	0.090	1.277	0.36	6.16	6.04	0.26	1.88	39.35	53.35	1.10
		76/86-120	8.5	7.0	0.029	23	28	49	C	0.540	1.08	29.89	11.11	54.60	78	0.041	0.559	0.24	5.24	3.66	0.2	1.80	-	-	-
		120-180	8.7	7.2	0.03	27	30	43	C	0.490	2.34	25.95	9.38	39.20	97	0.027	0.279	0.50	5.38	4.04	1.08	2.28	-	-	-
4c2	S-13	0-20	6.7	5.4	0.026	29	26	45	C	0.310	1.75	25.60	8.89	57.80	63	0.230	3.112	4.54	17.12	26.2	0.54	2.20	45.20	40.05	0.90
		20-75	7.2	5.7	0.02	19	24	57	C	0.340	1.32	29.14	9.05	57.80	69	0.125	1.875	1.12	14.64	22.48	0.44	2.40	43.84	48.61	1.09
		75-105	8.0	6.1	0.009	19	30	51	C	0.48	1.47	29.84	9.63	51.20	81	0.069	1.037	0.32	6.74	6.84	0.36	2.30	59.93	34.18	1.07
		105-200	8.6	7.1	0.024	21	26	53	C	0.50	1.44	31.44	9.71	44.60	97	0.027	0.359	0.32	5.10	3.32	0.34	1.64	-	-	-
3a1	S-14	0-24	7.8	6.2	0.025	25	18	57	C	0.29	1.57	28.00	7.08	53.00	70	0.119	2.075	14.30	6.88	7.02	0.38	2.10	47.72	26.55	0.94
		24-50	7.5		0.018	29	28	43	C	0.280	2.63	24.40	6.67	44.00	77	0.154	2.135	14.08	8.18	23.72	0.64	2.02	46.96	25.35	1.05
		50-90	7.4		0.01	17	46	37	ZCL	0.390	3.44	26.15	7.49	47.60	79	0.118	1.476	2.70	4.40	11.04	0.22	1.64	52.46	30.46	1.15
		90-160	8.1		0.027	25	22	53	C	0.510	2.65	20.96	5.68	41.20	72	0.073	0.938	0.68	4.66	4.32	0.32	1.76	-	-	-
		160-200+	8.2		0.024	13	42	45	C	0.800	1.68	28.88	6.71	40.20	95	0.025	0.239	0.56	4.92	3.40	0.26	1.66	-	-	-
4c1	S-15	0-25	6.4		0.015	19	24	57	C	0.370	2.48	25.95	8.07	48.60	76	0.216	3.012	3.32	15.86	31.46	0.54	1.28	48.61	27.86	0.85
		25-50	6.7			15	18	67	C	0.350	1.30	17.66	6.09	50.00	51	0.129	1.975	1.64	13.36	24.02	0.32	2.10	54.14	32.46	1.17
		50-70	7.0		0.006					0.490	1.35	31.54	8.89	49.20	86	0.104	0.878	0.42	10.08	16.66	0.44	2.18	57.78	34.63	1.15

C:clay,Cl:clay loam and ZCL: silt clay loam

