SOILS OF MUTEFECHA

IRRIGATION DEVELOPMENT PROJECT

first Draft

1. INTRODUCTION

This report contains the findings of the soil survey conducted in December 2000 for irrigation development at Mutefecha, located in Oromya zone of the Amhara Regional State. The project aimed to irrigate some 200 ha of land on the left-bank of Hunte River.

The objectives of the soil survey were to investigate and map the soils of the project area at 1:2000 scale and characterize their physical and chemical properties to determine the soil fertility and irrigation suitability.

The report is structured in such a way that overall description of the project area is given in Chapter 2. This is followed by the description of the method and procedures followed for the conduct of the survey. Chapter 4 gives detail accounts of the mapping units identified in the project area by the survey as regards to their land as well as physical and chemical properties of the soils. A summary of the overall physical and chemical properties of the soils and their interpretation are given in Chapter 5. The conclusions drawn and the proposed recommendations constitute the last part of the report. The soil map of the area is presented in a separate sheet, while detailed data generated during the survey are Annexed to the report.

2. THE PROJECT AREA

2.1 Location and Access

The project area is located in Oromya Special Zone of the Amhara National Regional State. It is at about 250 Km north of Addis Ababa. Its geographical extent is from 10° 6' 50" to 10° 7' 5" northern latitude and from 39° 55' 52" to 39° 57' 12" eastern longitude.

The Addis Ababa - Dessie asphalt road provides the primary access to the area. The road letting to the project area bifurcates from this main road at about 1 Km from the Jewaha town to Kemisie, Zonal town.

2.2 Climate

2.3 Physiography and Geology

The project area is one of the troughs paralleling the Ethiopian Rift Valley along its western escarpments. It has a very gently sloping footslope and a flat to concave alluvial plain with a gradient of 3 to 5, and 0 to 1% slope respectively. It has a low relief difference with altitude ranging from 1165 to 1200 meters. In some places where the slope is very flat, water logging occur.

The geology of the area consists mainly of thick alluvial deposits with some colluvium on the footslopes, derived from the adjacent basaltic mountains. The nature of the soils in the area are influenced, apart from the alluvial process, by slope and physiographic position. On concave alluvial plains due to relatively higher moisture content deep heavy clay soils have developed, whereas footslopes get stony close to the mountain. The drier climate has render the accumulation of carbonates in the profile and hence the higher soil pH.

2.4 Land Use

Rainfed as well as irrigated cropping is a long standing practice in the area. Livestock rearing, once had been the only livelihood of the community, has now almost equal importance for the farmers. Sorghum and maize are the major crops cultivated in the project area. However, due to the current market demand the production of fruits and vegetables such as pepper, onion, tomato, papaya and mango is increasing particularly in irrigated plots. A

pest attack to sorghum is also a reason for the land use change. The majority of the farmers employ oxen plow cropping. Only few individuals were seen to rent a tractor.

3. SURVEY METHODS

3.1 Office Work

Prior to commencement of the field soil investigation secondary data such as aerial photographs (AP's) and topographic maps were collected and analyzed. It was followed by a reconnaissance field visit to the area, during when a preliminary physiography oriented map of the project area was developed.

3.2 Field Work Procedure

The soil investigation fieldwork was conducted in three successive steps:

a) ***Auger observation:*** After having verified the preliminary map, auger observations were made to study land and soil characteristics of the area. 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 traverse type whereby observation traverses cut-across soil boundaries. In some irregular units additional observations were made to study the variability. The location of all the observation points were read by a GPS for their latitude and longitude. In total 20 auger observations were made.

b) ***Profile sampling:*** For further soil characterization, soil profile pits were dug on four representative sites. The soil profile descriptions were recorded on standard form for soil profile description. In total 12 disturbed and 8 pF-ring samples were collected from natural soil horizons.

c) ***Infiltration Test:*** An attempt has been made to measure infiltration rates using the double-ring infiltrometer around the profile pits. However, it was not possible to conduct the test on the cracking heavy clay soils on the concave alluvial plain even with heavy pre-wetting. In general, infiltration test was conducted on two sites using the water form Hunte River.

3.3 The Soil Map and Legend

Homogeneous land units have been distinguished on the basis of the following two major land/soil characteristics: slope and soil texture.

Slope percentage in the project area ranges from 0 to 5 and land facets were grouped according to their general slope classes at the first level of generalization. Then the uniform slope areas were further subdivided on the basis of surface texture. Thus, the soil map of the project area indicates areas that are uniform in slope and soil texture (Table 1). Soil depth has less importance as mapping unit distinguishing criteria because soils of the project area are all deep. In general, four different mapping units have been identified (Table 2).

Table 1. Distinguishing criteria of the mapping units

Slope %		*Surface Texture (0 - 30cm)*	
Range	*Code*	*Type*	*Code*
0 - 0.5	1	Heavy clay	a
1 - 2	2	Loam	b
3 - 5	3	Silty clay loam	c

		Silty clay	d

On the soil map a land unit is indicated by at least two elements: a number indicating the first criterion (slope class), a lower case letter indicating the second criterion (soil texture). The area of the mapping units was measured by a planimeter.

1a: wherein, **1**-slope class, **a** - soil texture

Table 2. List of mapping units identified in the project area

Mapping unit	*Slope (%)*	*Soil depth (cm)*	*Texture (0 - 30 cm)*	*Soil Type (FAO,)*
1a	0 - 0.5	>150	Heavy Clay	Vertisol
2b	1 - 2	>150	Loam	Luvisol
2c	1 - 2	> 150	Silt clay loam	Luvisol
3d	3 - 5	100 - 150	Silty clay	Vertisol

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 2 mm 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. Electrical conductivity *(EC)* was measured by EC 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 *(CEC)* 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. *Bulk density* was determined from pF-ring samples and *moisture content* at 0.33 and 15 bar suction was determined by closed pressure plate extraction method.

4. DESCRIPTION OF SOIL MAPPING UNITS

The distribution of the different soil mapping units in the project area are shown in the soil map and their major physico-chemical properties are given in Table 1. Each soil mapping unit is described below.

4.1 Mapping unit: 1a

This unit refers to the somewhat poorly drained soils that occur on concave (depressed) alluvial plain (with 0 to 0.5 percent slope) in the central part of the project area.

Soils of the unit are very deep (>150 cm) and black (10YR 2/1) in color. The texture is heavy clay with strong medium to coarse angular blocky structure. Polygonal surface cracks (about 1 cm wide) have been observed to a depth of 110 cm. These soils have the consistency that is hard when dry, firm when moist and sticky-plastic when wet.

The pH of the surface soil is around 8 and the average electrical conductivity of the upper 1m soil is 0.3 ds/m. The cation exchange capacity of the soils is high (49 Cmol (+)/kg soil) and it is highly base saturated (>75 %). The organic matter and total nitrogen content is medium (5 and 0.15% respectively), while available

phosphorous is also medium (3.8ppm). The maximum exchangeable sodium percentage (ESP) within 1m depth is 6 and its value increases to 12 below 1m depth.

4.2 Mapping unit: 2b

This unit refers to the well drained soils that occur on almost flat alluvial plain (with 1 to 2 percent slope) in the western part of the project area.

Soils of the unit are very deep (>150 cm) and grayish brown (10YR 5/2) in color. The texture is loam with massive to weak fine columnar structure. These soils have the consistency that is soft when dry, friable when moist and slightly sticky- non plastic when wet.

The pH of the surface soil is around 10 and the average electrical conductivity of the upper 1m soil is 1.8 ds/m (1:2.5 soil-water suspension). The cation exchange capacity of the soils is high (48 Cmol (+)/kg soil) and it is fully base saturated (100%). The organic matter and total nitrogen content is low(1.6 and0.05% respectively), while available phosphorous is very high (31ppm). The maximum exchangeable sodium percentage (ESP) within 1m depth is very high (85).

4.3 Mapping unit: 2c

This unit refers to the well drained soils that occur on almost flat alluvial plain (with 1 to 2 percent slope) in the southern part of the project area.

Soils of the unit are very deep (>150 cm) and very dark gray (10YR 3/1) in color. The texture is silt loam with weak medium angular blocky structure. These soils have the consistency that is slightly hard when dry, friable when moist and slightly sticky- non plastic when wet.

The pH of the surface soil is around 8.1 and the average electrical conductivity of the upper 1m soil is 0.1 ds/m. The cation exchange capacity of the soils is medium to high (30 Cmol (+)/kg soil) and it is fully base saturated (100%). The organic matter and total nitrogen content is medium(4.8 and 0.17% respectively), while available phosphorous is low to medium (12.8 ppm). The maximum exchangeable sodium percentage (ESP) within 1m depth is low (2).

4.4 Mapping unit: 3d

This unit refers to the well drained soils that occur on gently sloping footslope (with 3 to 5 percent slope) in the northern and north western part of the project area.

Soils of the unit are very deep (>150 cm) and very dark brown (10YR 2/1) in color. The texture is heavy clay with moderate medium sub-angular blocky structure. Polygonal surface cracks (about 1 cm wide) have been observed to a depth of 65cm. These soils have the consistency that is hard when dry, firm when moist and sticky-plastic when wet.

The pH of the surface soil is around 7.7 and the average electrical conductivity of the upper 1m soil is 0.08 ds/m. The cation exchange capacity of the soils is very high (50 Cmol (+)/kg soil) and it is highly base saturated (67 to 100%). The organic matter and total nitrogen content is medium (5.2 and 0.17% respectively), while available phosphorous is medium (16.8 ppm). The maximum exchangeable sodium percentage (ESP) within 1m depth is low (2).

Table 2. Some physical and chemical characteristics of the soil mapping units

Mapping unit	Slope %	Soil depth (cm)	Texture (0-30 cm)	pH H_2O	EC dS/m	OM %	T.N %	Av. P ppm
2b	1 - 2	>150	Loam	9 - 11	1.8	1.4	0.05	31.0
2c	1 - 2	>150	Silty clay loam	8.1 - 8.6	0.1	4.6	0.17	12.8
1a	0 - 0.5	>150	Clay	8.1 - 8.9	0.3	4.1	0.15	3.8
3d	3 - 5	100 - 150	Silty clay	7.7 - 8.7	0.08	4.7	0.17	16.8

Mapping unit	Exchangeable bases (cmol (+) Kg^{-1} soil)					BS	ESP	BD	Moisture content	Basic Infiltration
	Na	K	Ca	Mg	CEC	%		gcm^{-3}	cm/m	cmh^{-1}
2b	56.1	1.7	3.6	1.2	42.8	100	85	-		-
2c	0.6	3.3	28.1	4.8	28.4	100	2	1.04	15.4	3.2
1a	0.7	2.3	28.2	9.3	49.0	83	6	1.15	17.3	-
3d	0.3	3.4	25.1	4.9	50.6	67	2	1.13	13.3	4.8

5. PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOILS

5.1 Physical Properties

5.1.1 Soil depth

Soils of the project area are generally deep. Consolidated calcareous material occurs at about 1m depth in the footslope (Mapping unit 3d). Soils of the alluvial plain are deeper than 2m. In general there is no rooting depth limitation in the project area.

5.1.2 Texture

Soils of the project area are of medium to fine texture. Fine textured soils occur on the footslopes (Mapping unit 3d) and on the concave alluvial plain (Mapping unit 1a). Heavy clays on the alluvial plain may restrict drainage.

5.1.3 Bulk density

Bulk density values tend to slightly increase with depth. Surface soils have bulk density between 0.97 and 1.15 gcm^{-3}, which increases to 1.18 gcm^{-3} in subsurface layers. Thus, soils of the project area are not compact and do not pose problem for root penetration.

5.1.4 Infiltration rate

Fine textured soils of the project area (Mapping unit 1a and 3d) have relatively higher basic infiltration rate (4.8 cm hr^{-1}) as compared to the medium textured soils (3.2 cm hr^{-1}) of the alluvial plain (Mapping unit 2b and 2c). Cracks through fine textured soils, even after adequate pre-wetting, could be responsible for the relatively higher intake rate.

5.1.5 AWC and porosity

The Available Water holding Capacity (AWC) of the soils is high. Its amount in the upper 1m depth is between 13.3 and 17.3 cm. The total porosity of the soils decreases with depth and its volume percentage ranges from 55 to 68. The volume of macro-pores, which is equal to the total porosity less the volumetric water content at field capacity, varies from 2.3 to 30%. The clayey soils (Mapping unit 1a and 3d) have low macro-pores (Annex 3) as compared to the loamy soils, hence aeration problem is likely to occur at field capacity in clayey soils.

5.2 Chemical Properties

5.2.1 Soil reaction (pH)

Soils of the project area have alkaline reaction that increases with depth. The pH values range from 7.6 to 10.9. Soils of the mapping unit 2b have high pH values (9 to 11), probably due to a presence of sodium salts.

5.2.2 Soil salinity

The electrical conductivity of the soils (measured at 1:2.5 soil-water suspension) ranges from 0.06 to 2.6 dS cm^{-1}, the saturation extract equivalent of which is estimated to range from 0.15 to 6.5 dS cm^{-1}. High EC values are recorded in soils from mapping unit 2b. Thus, except mapping unit 2b, there is no salinity problem in the project area at present.

5.2.3 **The exchange complex**

The cation exchange capacity (CEC) of the soils in the project area is generally high (28 to 53 cmol/kg soil) and it is 60 to 100 % saturated by cations (Na, Ca, Mg and K). As far as cationic balance is concerned, there is high exchangeable sodium content in the soils of the mapping unit 2b and in subsurface soil horizons of the mapping unit 1a. The exchangeable potassium content, particularly in the topsoil, is greater than the sufficiency level (Robert d., 1990). Calcium and magnesium exist in sufficient amount except in mapping unit 2b.

5.2.4 **Soil sodicity**

The exchangeable sodium percentage (ESP) of the soils commonly ranges between 0 and 2. Exceptionally very high values (about 85) have been measured on soils form mapping unit 2b, and moderate to high values were also measured (6 to 12) in subsurface horizons of the soils of the mapping unit 1a. That the mapping unit 2b was probably caused by a hot-spring, dried up at present, as it has been informed by elders.

5.2.5 **Organic matter content**

The organic matter content of the soils decreases with depth and its amount is between 0.5 and 4.6%; equivalent to organic carbon content of 0.3 and 2.7% (which is low to medium). In general terms the organic matter content of the top soil is good.

5.2.6 **Total nitrogen**

The total nitrogen content of the soils is very low to medium. Its amount in the surface soil is within the range of 0.05 and 0.17% and decreases with depth. The relatively low nitrogen content is probably due to higher losses favored by the climatic and soils conditions.

5.27 **Available phosphorous**

The available phosphorous content has irregular distribution with depth. Its amount in the surface soil ranges between 4 and 11ppm, exceptionally high value (31) was determined in the mapping unit 2b. In general, the available phosphorous content in the project area is in the medium range.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Irrigation suitability

Taking into account the topography (particularly slope) as well as soil physical and chemical properties of the project area is suitable for irrigation development except the mapping unit 2b due to high salinity and sodicity. Thus, the mapping unit 2b should be used as salting ground for livestock, as it is now, and canals passing through should be lined to avoid contamination and possible change in irrigation water quality.

6.2 Soil and water management

Due to the amount (%) and nature of clay in the concave alluvial plain (mapping unit 1a) water logging and aeration problem could be caused up on irrigating the soils to saturation. Thus it is recommended to control the problem by frequent irrigation with low depth of application.

6.3 Soil fertility management

The results of the soil analyses indicate that potassium is present in sufficient amount in the project area. However, the nitrogen and phosphorous content tends to be slightly deficient. Thus it is likely that a response to N and P fertilizers could be obtained.

Annex 1. SOIL PROFILE DESCRIPTIONS

Date: 25/4/93

Pedon No. 1
Location: Mutefecha, N10° 6' 57.2", E39° 56' 29.4"
Author: Abayneh E.
Soil type: Fluvisol
Surrounding landform: Mountaimous
Physiographic position: Alluvial plain
Slope (%): 1
Land use/cover: Abandoned
Parent material: Alluvium
Moisture condition: Slightly moist
Climate: Tropical
Drainage class: Well
Permeability:
Erosion a) At site: none
b) Surrounding: Slight sheet

Horizon Description

0 - 30cm Grayish brown (10YR 5/2) moist; loam; massive; soft (dry), friable (moist), slightly sticky-none plastic (wet); many fine and medium pores; calcareous; claear and smooth boundary.

30 - 100+cm Light brownish gray (10YR 6/2) moist; clay loam; weak fine columnar; friable, slightly sticky-slightly plastic; many fine pores; calcareous; common medium carbonate concretions; gradual and smooth boundary.

Date: 26/4/93

Pedon No. 2
Location: Mutefecha, N10° 6' 42.2", E39° 56' 52.1"
Author: Abayneh E.
Soil type: Fluvisol
Surrounding landform: Mountainous
Physiographic position: Alluvial plain
Slope (%): 1
Land use/cover: Maize, sorghum, irrigated vegetables and fruits
Parent material: Alluvium
Moisture condition: Slightly moist
Climate: Tropical
Drainage class: well
Permeability:
Erosion a) At site: None
b) Surrounding: severe sheet and riverbank

Horizon Description

0 - 30cm Very dark gray (10YR 3/1) moist; silt loam; weak medium angular blocky; hard (dry), friable (moist), slightly sticky-none plastic (wet); many medium pores; slightly calcareous; many fine roots; clear and smooth boundary.

30 - 120cm Very dark gray (10YR 3/1) moist; clay; weak fine angular blocky; friable, sticky-none plastic; many fine to medium pores; calcareous (soft powdery); few fine roots; gradual and smooth boundary.

120 - 180+cm Brown (10R 4/3) moist; clay loam; weak fine angular blocky; friable, slightly sticky-slightly plastic; common fine to medium pores; strongly calcareous.

Date: 26/4/93

Pedon No. 3
Location: Mutefecha, N10° 6' 53.7", E39° 56' 51.8"
Author: Abayneh E.
Soil type: Vertisol
Surrounding landform: Mountainous
Physiographic position: Valley bottom
Slope (%): 0.5
Land use/cover: Maize, sorghum, tef
Parent material: Alluvium
Moisture condition: Moist below 25cm ***Climate:*** Tropical
Drainage class: Somewhat poor ***Permeability:***
Erosion a) At site: None
b) Surrounding: None

Horizon Description

0 - 30cm Very dark gray (10YR 3/1) dry and black (10YR 2/1) moist; clay; strong medium angular blocky; 1cm thick by 35cm deep vertical cracks; hard (dry), firm (moist), very sticky-plastic (wet); many fine to medium pores; many fine roots; clear and smooth boundary.

30 - 110cm Black (10YR 2/1) moist; clay; strong medium angular blocky; 0.5cm thick by 50cm deep vertical cracks; firm, very sticky-plastic; few faint slickensides on pedfaces; many fine to medium pores; slightly calcareous; few fine roots; gradual and smooth boundary.

110 - 170+cm Brown (10YR 5/3) moist; clay loam; weak medium sub-angular blocky; friable, sticky-slightly plastic; many medium pores; calcareous.

Date: 26/4/93

Pedon No. 4
Location: Mutefecha, N10° 7' 12.1", E39° 57' 8.3"
Author: Abayneh E
Soil type: Vertic Cambisol
Surrounding landform: Mountainous
Physiographic position: Footslope
Slope (%): 3
Land use/cover: Maize
Parent material: Alluvium - colluvium
Moisture condition: Slightly moist
Climate: Tropical
Drainage class: Well
Permeability:
Erosion a) At site: Sight sheet
b) Surrounding: Moderate sheet

Horizon Description

0 - 25cm Dark grayish brown (10YR4/2) dry and very dark brown (10YR 2/2) moist; clay; moderate medium sub-angular blocky; 2cm thick by 25cm deep vertical cracks; hard (dry), firm (moist), sticky-slightly plastic (wet); many fine to medium pores; common fine roots; clear and smooth boundary.

25 - 65cm Brown (10YR 2/2) moist; clay loam; weak fine crumb; 1cm thick by 40cm deep vertical cracks; friable, slightly sticky-slightly plastic; common fine to medium pores; slightly calcareous; few fine roots; clear and smooth boundary.

65 - 140cm Very dark grayish brown (10YR 3/2) moist; clay; weak medium angular blocky; friable, sticky-plastic; very few distinct clay cutans on pedfaces; common fine pores; calcareous; few fine roots; abrupt and smooth boundary.

140 - 170cm+ Dark grayish brown (10YR 4/2) moist; clay loam; massive; slightly firm, slightly sticky-none plastic; slight carbonate cementation; many fine pores; strongly calcareous.

Annex 2. INFILTRATION MEASUREMENTS

Project: *Mutefecha*				**Ring No.** *Profile No. 2*			
Source of water: *Hunte river*		**Date:** *26/4/93 E.C*		**Author:** *Abayneh E.*			
Depth of insertion of ring (cm): *8 cm*				**Soil type:** *Fluvisol*			
Surface feature: *Cultivated field*							
Local Time	**Interval (min)**	**Cumulative time (min)**	**Depth of water in infiltration ring (cm)**	**Intake (cm)**	**Cumulative intake (cm)**	**Infiltration rate (cm/hr)**	
						Immediate	**Mean**
9:05	0	0	33.0	0.0	0.0		
	5	5	35.0	2.0	2.0	24	24.0
	5	10	37.0	2.0	4.0	24	24.0
	5	15	37.3	0.3	4.3	3.6	17.2
	5	20	37.8	0.5	4.8	6.0	14.4
9:30	5	25	38.3	0.5	5.3	6.0	12.7
	5	30	38.7	0.4	5.7	4.8	11.4
	5	35	39.1	0.4	6.1	4.8	10.5
	5	40	39.5	0.4	6.5	4.8	9.7
	5	45	40.0	0.5	7.0	6.0	9.3
	5	50	40.4	0.4	7.4	4.8	8.9
10:00	5	55	40.8	0.4	7.8	4.8	8.5
	5	60	41.2	0.4	8.2	4.8	8.2
	5	65	41.6	0.4	8.6	4.8	7.9
	5	70	42.0	0.4	9.0	4.8	7.7
	15	85	43.0	1.0	10.0	4.0	7.1
	15	100	44.0	1.0	11.0	4.0	6.6
11:00	15	115	45.0	1.0	12.0	4.0	6.3
	15	130	45.7	0.7	12.7	2.8	5.9
	15	145	46.5	0.8	13.5	3.2	5.6
	15	160	47.3	0.8	14.3	3.2	5.4
12:00	15	175	48.1	0.8	15.1	3.2	5.2
	15	190	48.9	0.8	15.9	3.2	5.0

Pre-wetting: 48 hr before
Depth of percolation after infiltration test: 65 cm

Project: *Mutefecha*	**Ring No.** *Profile No. 4*

Source of water: *Hunte River*		**Date:** *27/4/93 E.C*			**Author:** *Abayneh E.*		
Depth of insertion of ring (cm): *7 cm*					**Soil type:** *Vertic Cambisol*		
Surface feature: *Harvested field*							
Local Time	**Interval (min)**	**Cumulative time (min)**	**Depth of water in infiltration ring (cm)**	**Intake (cm)**	**Cumulative intake (cm)**	**Infiltration rate (cm/hr)**	
						Immediate	**Mean**
8:20	0	0	29.0	0.0	0.0		
	5	5	31.1	2.1	2.1	25.2	25.2
	5	10	33.1	2.0	4.1	24.0	24.6
	5	15	34.9	1.8	5.9	21.6	23.6
	5	20	36.5	1.6	7.5	19.2	22.5
	5	25	38.0	1.5	9.0	18.0	21.6
	5	30	39.2	1.2	10.2	14.4	20.4
	5	35	40.4	1.2	11.4	14.4	19.5
	5	40	41.5 →34.1	1.1	12.5	13.2	18.7
	5	45	35.4	1.3	13.8	15.6	18.4
	5	50	36.5	1.1	14.9	13.2	17.9
	5	55	37.5	1.0	15.9	12.0	17.3
	5	60	38.6	1.1	17.0	13.2	17.0
	5	65	39.6	1.0	18.0	12.0	16.6
	5	70	40.6	1.0	19.0	12.0	16.3
	5	75	41.6	1.0	20.0	12.0	16.0
	5	80	42.4 →34.0	0.8	20.8	9.6	15.6
	5	85	34.8	0.8	21.6	9.6	15.2
	5	90	35.8	1.0	22.6	12.0	15.1
	5	95	36.8	1.0	23.6	12.0	14.9
	5	100	37.6	0.8	24.4	9.6	14.6
	5	105	38.4	0.8	25.2	9.6	14.4
	5	110	39.2	0.8	26.0	9.6	14.2
	5	115	39.9	0.7	26.7	8.4	13.9
	5	120	40.6	0.7	27.4	8.4	13.7
	5	125	41.2	0.6	28.0	7.2	13.4
	5	130	41.8	0.6	28.6	7.2	13.2
	5	135	42.6 →35.8	0.6	29.2	7.2	13.0
	10	145	37.2	1.4	30.6	8.4	12.7
	10	155	38.4	1.2	31.8	7.2	12.3
	10	165	39.6	1.2	33.0	7.2	12.0
	10	175	40.2	0.6	33.6	3.6	11.5
	10	185	41.7	1.5	35.1	9.0	11.4
	10	195	42.6	1.1	36.2	6.6	11.1
	10	205	43.6	1.0	37.2	6.0	10.9
	10	215	44.4	0.8	38.0	4.8	10.6

Pre-wetting: *48 hr before*
Depth of wetting after infiltration test: *75 cm*

Annex 3. Analytical data of the representative pedons

Map	Pedon	Depth	pH H2O	EC	Texture				Exchangeable cations (cmol/kg soil)					Bas.Sa	ESP	T.N	O.C	Av.P	BD	Moisture Content (W%)		Porosity (V%)	
Unit	No.	cm	1:2.5	ds/m	Sand	Silt	Clay	Class	Na	K	Ca	Mg	CEC	%		%	%	PPm	gcm^{-3}	0.33 bar	15 bar	Total	Macro
2b	1	0-30	9.94	2.6	32	48	20	L	56.10	1.66	3.59	1.17	42.8	146	131	0.08	0.798	31.0	-	-	-		
		30-60	10.92	0.9	20	44	36	SiCL	58.81	1.05	0.95	0.42	39.4	155	149	0.02	0.299	8.2	-	-	-		
2c	2	0-30	8.13	0.16	16	46	38	SiCL	0.63	3.32	28.09	4.83	28.4	130	2	0.21	2.693	12.8	0.97	40.79	21.59	63	22.5
		30-120	8.41	0.09	26	42	32	CL	0.50	2.39	23.2	7.25	32.0	104	2	0.10	1.296	2.8	1.12	35.18	22.69	58	18.6
		120-180	8.59	0.09	32	48	20	L	0.88	1.9	24.7	12.08	37.0	107	2	0.04	0.698	3.4	-	-	-		
1a	3	0-30	8.08	0.1	24	36	40	C	0.70	2.26	28.24	9.33	49.0	83	1	0.18	2.394	3.8	1.12	42.50	27.08	58	8.4
		30-110	8.87	0.17	20	32	48	C	2.88	1.04	27.45	12.66	49.8	88	6	0.10	1.715	1.2	1.15	43.35	28.29	57	7.2
		110-170	8.42	0.68	26	40	34	CL	5.99	0.8	20.51	12.66	51.0	78	12	0.04	0.399	1.0	1.18	43.21	27.00	55	4
3a	4	0-25	7.67	0.12	16	44	40	SiC	0.29	3.39	25.10	4.91	50.6	67	1	0.23	2.793	16.8	1.15	45.49	27.50	57	4.7
		25-65	8.04	0.09	26	36	38	CL	0.25	1.46	35.78	5.08	53.0	80	0	0.18	2.074	5.0	0.84	45.23	28.52	68	30
		65-140	8.21	0.060	20	38	42	C	0.53	0.86	44.96	6.41	49.6	106	1	0.13	1.775	3.2	1.13	48.4	30.64	57	2.3
		140-170	8.74	0.070	24	34	42	C	0.46	0.21	16.02	2.17	18.6	101	2	0.07	1.137	10.0	-	-	-		